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**IMPACT OF VIRTUAL CHEMISTRY LAB SOFTWARE (VCLS) AND GENDER ON THE  
ACQUISITION OF PRACTICAL SKILLS IN ACID-BASE TITRATION AMONG SECONDARY  
SCHOOL STUDENTS**

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**IMPACT OF VIRTUAL CHEMISTRY LAB SOFTWARE (VCLS) AND GENDER ON THE ACQUISITION OF PRACTICAL SKILLS IN ACID-BASE TITRATION AMONG SECONDARY SCHOOL STUDENTS**

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**Abstract**

The use of a virtual laboratory allows students to experience practical activities in the absence of adequate laboratory facilities however, the extent to which it can be used in the acquisition of practical skills needed to be determined. A quasi-experimental research design of a 2x2x2 non-randomized factorial matrix was adopted. 166 students in their intact classes comprising 62 male and 104 female students from six schools in Lagos State, Nigeria were used for the study. The schools were sampled based on the availability of functional chemistry laboratories for the control group and the availability of ICT resources for the experimental group. Three schools were selected for each group. The students in the experimental group carried out practical activities with Virtual Chemistry Laboratory Software (VCLS) while the students in the control group used the Conventional Laboratory Manual (CLM). Data were obtained with the use of the Chemistry Practical Skills Test (CPST) and the analysis was carried out with the use of descriptive statistics and ANOVA. The findings showed that chemistry students acquired practical skills with the use of VCLS just as with the use of CLM. Also, female chemistry students acquired practical skills more than their male peers. The use of virtual laboratories is therefore highly recommended in carrying out chemistry practical in secondary schools.

**Introduction**

A virtual laboratory is an environment that is interactive. It involves the use of hands-on activities but without the use of real equipment and apparatus in carrying out those activities. Virtual laboratories are simulated versions of traditional laboratories; the students are provided with objects that are not real but are simulated representations of real objects (Faour and Ayoubi, 2018). Virtual laboratory or simply virtual lab makes available tools and materials, for students to perform experiments set on a computer instead of the traditional laboratory (Babateen, 2011). These experiments could be saved on CDs or websites. The use of this form of technology for carrying out practical activities is becoming popular in schools (Bortnik et al., 2017). It has been in use even before the Covid 19 pandemic, which

forced many schools to get involved in digital and online teaching. The use of a virtual lab has the potential of improving students' academic performance and acquisition of practical skills in science subjects and especially chemistry.

Virtual Chemistry Laboratory Software (VCLS) when used for teaching science practical synergizes students of similar or differing academic capabilities to work together or differently in achieving the objectives of practical works and in building self-confidence, self-esteem, skills acquisition, and scientific attitudes among learners (Topping, 2005; CISCO 2012; Ajeyalemi and Okunuga, 2013; Okunuga and Ajeyalemi, 2018). In the natural sciences and chemistry, the experimental (laboratory) approach is the most effective method of acquiring knowledge and skills thereby making students learn by observing and doing. Other studies reported that chemistry practical cannot be effectively conducted in a conventional laboratory due to learners' safety, poor self-confidence, inadequate time, and effort for accurate experiments (Okebukola, 2006; Njoku, 2007; Obrentz, 2012). These limitations, therefore, demand appropriate alternative that requires digital literacy, especially in the use of educational technologies. Thus, experiments can be carried out in schools with the use of computer simulations or animations.

## **Practical Skills in Chemistry**

Practical skills in chemistry, which is an indication of the learned process skills can be acquired and transferred through training that involves practical activities. According to Ajaja (2010), process skills are fundamental to science. They allow everyone to investigate and reach conclusions. Ozgelen (2012) defined science process skills as abilities, potential as well as all the technical "know-how" which can be developed in a child, and which can be employed in carrying out a mental and physical operation in science. According to Ango (2011), there are two categories of science process skills. These are the basic and integrated science process skills. The skills of observing, measuring, classifying, using numbers, communicating, inferring, using space or time relationships, and questioning are the basic science skills. These are the skills that secondary school science students are expected to acquire. The integrated science process skills are the higher-order skills and comprise controlling and manipulating variables, hypothesizing, defining operationally, formulating models, designing an experiment, and interpreting data.

The West African Examination Council (WAEC, 2014) in the examination syllabus given to students to prepare for the Secondary School Certificate Examination (SSCE) listed the objectives of studying science in secondary schools to include understanding of basic science concepts, acquisition of laboratory/practical skills, awareness of the linkage between science and industry, awareness of the linkage between science and everyday life in terms benefits and hazards, among others. If these objectives are to be achieved, the teaching and learning of science must of necessity involve experimentation and the use of hands-on and mind-on activities for a better understanding of the scientific concepts (Achimugu, 2014). These objectives of studying science require that science is taught using experimentation and practical methods rather than a theoretical approach.

Hands-on experiences enhance the development of the spirit of inquiry in students. It also motivates them to develop the right attitude towards the handling of scientific tools and materials as well as promotes the acquisition of process skills (Omiko, 2015). However, in schools where there are no laboratories or where the laboratories are inadequately equipped, students having hands-on experiences become a mirage. Hence, students end up taking practical classes a few weeks before WAEC or National Examination Council (NECO) practical senior school certificate examinations (Okunuga, 2011). These students, in consequence, will lack the acquisition of practical skills due to the unavailability of a real laboratory. The virtual lab is necessary for augmenting these inadequacies thereby providing the students with requisite practical skills for their improvement in chemistry and other sciences.

In the Chief Examiner's report, poor performances of students in science subjects were attributed factors, which include students not being familiar with common laboratory equipment and apparatuses, inadequate knowledge or understanding of simple basic principles and practical concepts and processes. Many students also do not understand the procedures of practical activities (WAEC, 2015). Thus, students are not able to use laboratory equipment effectively as well as apply the principles in practical activities leading to a low level of acquisition of practical skills. There is therefore the need for a more effective approach to enable students to improve in practical skills acquisition.

Babateen (2011) noted that the acquisition of practical skills in students can be promoted with the use of virtual laboratories. These skills are needed in developing scientific ideas in students and in making them become independent thinkers. He also stated that the virtual laboratory environment is rich in technology, which will enhance the motivation of students greatly as we now live in the technological age. Further, the availability and use of digital devices and the

recent Covid 19 pandemic have encouraged the use of technology among students. Process skill acquisition is the prerequisite to the acquisition of higher-order skills. Practical skills are subsumed in process skills and these skills are acquired as students carry out practical activities in the laboratory. Ajaja (2010) observed that there is a serious educational gap in bringing process skills into the classroom and in the training of teachers to use them effectively. The use of a virtual chemistry lab that involves the application of creativity and the use of technology can bridge the gap and promote the acquisition of practical skills in chemistry.

## **Virtual Laboratories, Academic Performance, and Skills Acquisition**

Students are given opportunities to learn by doing with the use of virtual laboratories. They are provided with interesting, enjoyable, and intriguing hands-on activities, which can enhance meaningful discovery and active interactions in the classroom. According to Lkhagva et al., (2012), the students tend to perform even better than those learning through traditional methods. Bozkurt and Ilik (2010) also found in their study that the students that were taught with the use of computer simulations had a better achievement than those that were taught with the traditional method. Tuysuz (2010) carried out a study to ascertain the influence of virtual laboratory on 341 chemistry students' achievements and attitudes. The results showed that the attitudes of the students toward chemistry depend and vary on the teaching methods used by the teacher. It was also found that the use of virtual laboratory influenced students' achievement and their attitude toward chemistry positively when compared with the use of the traditional method. It was therefore concluded that it is appropriate and convenient to use computers in science teaching.

In addition, it was found by Tatli and Ayas (2012) that students exposed to the virtual lab had significant improvement in their performance in chemistry practical activities more than those that used the traditional laboratory method. Flint and Stewart (2010) also reported that it was less expensive and faster to use a virtual lab than the traditional laboratory method. They added that the same learning outcomes were achieved provided the students were already familiar with the laboratory techniques. This is to suggest that virtual labs can be used to complement the traditional laboratory method, especially in chemistry practical activities, which can be expensive to carry out using the traditional laboratory. Pyatt and Sims (2012) found that the virtual lab increased the motivation of students, and their desire to attend lectures and carry out laboratory activities. They believed the use of virtual laboratories with students is safe and less expensive. It provides an environment that is ideal for students to develop practical skills in the process of learning. Therefore, this study was carried out to investigate the impact of virtual labs on chemistry students' acquisition of practical skills.

## **Skills Acquisition and Gender**

Many studies have shown different viewpoints and conclusions on the influence of the gender of students and skills acquisition. Olatoye and Olasheinde (2014) found that gender has no significant effect on science students' achievement and skills acquisition. Raimi (2010), in the same vein, found that the gender of students should not be associated with their performance. He stated further that both male and female students will achieve equally if they are exposed to the right teaching and learning process as well as given the same opportunity. However, in another study, it was found that female students performed better than male students when they were taught electrolysis using different technological tools (Etiubon, 2011) while male students were found to perform better in chemistry than female students by Ezeudu and Obi (2013). The mean scores of the male students were higher than those of the female students. The inconclusiveness of the influence of gender on students' academic performance led to its inclusion in this study as an intervening variable.

## **Statement of the Problem**

At secondary schools, most of the problems faced during chemistry practical are the unavailability and inadequacies of apparatuses, chemicals, and technical staff for the conduct of practical activities. This is because the cost of funding and maintenance of a standard chemistry laboratory is very high as compared to the use of a virtual laboratory, though it has its challenges too. In most cases, the apparatuses used in a conventional chemistry laboratory are fragile and expensive while the chemical reagents and other consumables must be replenished periodically. Also, the students cannot practice acid-base titrations on their own at home or outside the laboratory. In addition, some chemicals are hazardous and may endanger students' lives. These and some other deficiencies in the use of conventional laboratories can be taken care of to some extent with the use of virtual laboratories. To overcome some of these challenges

associated with chemistry laboratory activities and to improve the practical skills acquisition of the students, there is a need for the application of virtual laboratory to supplement classroom demonstration in the absence of a physical laboratory. The virtual lab can thus be an innovation in the Nigerian education system, particularly at the secondary school level, therefore, this study examined the effect of virtual Chemistry laboratory on the acquisition of practical skills among secondary school chemistry students.

Also, in most public-school classrooms, teachers are expected to assist students during practical work amid inadequate laboratory consumables and non-consumables. This necessitated the need to address more efficient ways of enhancing achievement and skills acquisition during laboratory activities and determining the extent to which gender could influence students' achievement and practical skills acquisition.

### **Objectives of the study**

The purpose of this study is to examine the impact of VCLS on the acquisition of practical skills of chemistry students.

1. examine the impact of VCLS on the acquisition of practical skills of secondary school chemistry students in acid-base titrations
2. determine the influence of gender on the acquisition of practical skills of secondary school chemistry students in acid-base titrations.

### **Research Questions**

The following research questions were raised.

1. What is the impact of VCLS on the acquisition of practical skills of secondary school chemistry students in acid-base titrations?
2. To what extent will gender (female and male) influence the acquisition of practical skills of secondary school chemistry students in acid-base titrations?

### **Research Hypotheses**

The following null hypotheses were tested

H<sub>01</sub>: there is no significant effect of VCLS on the acquisition of practical skills of secondary school chemistry students in acid-base titrations.

H<sub>02</sub>: there is no significant influence of gender (female and male) on the acquisition of practical skills of secondary school chemistry students in acid-base titrations

### **Methodology**

The research design used for this study was the quasi-experimental design where intact classes were subjected to VCLS (treatment) and conventional laboratory (control) on a 2x2x2 non-randomized factorial matrix.

Education District (IV) was randomly selected from the six Education Districts in Lagos State. Education District IV comprises schools in Apapa, Surulere and Lagos Mainland Local Government Areas. A letter of authority to carry out research work in some selected schools in the district was collected from the Tutor General of the District. Six schools were purposively selected from the senior secondary schools in the district. The purposive selection was based on the availability of a functional chemistry laboratory for the control group and the availability of ICT resources for the experimental group. In each of these schools, students in all the arms of senior secondary II (SS-II) science class were used. Three schools that met up with the criteria of the availability of ICT were selected as the experimental group while the other three were used as the control group. Also, all the chemistry teachers of the intact classes took part in the study. This is to make for the internal consistency of the sample. A preliminary study was conducted to collect data from selected schools based on the criteria for purposive sampling.

Research Assistants and Chemistry teachers in selected schools were trained on the use of the teaching manuals. They were trained with the adapted Teaching Manual on Virtual Chemistry Laboratory Software (TMVCLS) of the American Chemical Society (ACS) and the Teaching Manual on Conventional Laboratory (TMCL) developed by the researchers. The experimental group used the (TMVCLS) while others in the control group used the TMCL. Students

in the experimental group were taught with the VCL Software installed on the computers and laptops used for the study. They were then allowed to carry out given virtual practical activities based on acid-base titrations while students in the control group were exposed to a conventional laboratory manual. Data was collected with the use of the Chemistry Practical Skills Acquisition Test (CPSAT). The test consists of fifteen items to determine the extent to which chemistry students have acquired practical skills. Each item was given a score of one if right and a score of zero if wrong. The maximum score a student can obtain was therefore fifteen. The reliability of the instrument was determined using Cronbach Alpha and found to be 0.84. The test was also administered as a post-test for the two groups.

## Results

The research questions that were raised were answered using descriptive statistics. The hypotheses were tested using Analysis of Variance (ANOVA).

To answer the first research question, what is the impact of VCLS on the acquisition of practical skills of secondary school chemistry students in acid-base titrations? The descriptive statistics of mean and standard deviation are shown in Table 1.

TREATMENT	GENDER	Mean	Std. Deviation	N
VCL	MALE	11.0227	1.24804	44
	FEMALE	11.8500	1.66545	60
	Total	11.5000	1.55170	104
TM	MALE	10.7222	1.40610	18
	FEMALE	12.4545	1.45402	44
	Total	11.9516	1.63394	62
Total	MALE	10.9355	1.29147	62
	FEMALE	12.1058	1.60047	104
	Total	11.6687	1.59312	166

Table 1: Descriptive Statistics of Mean  
Dependent Variable: SAT TOTAL

Table 1 shows that the mean value of students' Skill Acquisition Test score with the use of VCLS is 11.5000 while those that used TM is 11.6687. These mean values are high when compared to the maximum value of 15. Also, the mean value with the use VCLS is just about the same as that of the use of TM though that of TM is slightly higher than that of VCLS (mean difference of 0.1687). It can therefore be inferred that chemistry students can acquire practical skills with the use of VCLS just as they can with the use of the traditional method.

To test the hypotheses, the ANOVA analysis is presented in Table 2

Table 2: Tests of Between Subjects Effects

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	121.299 <sup>a</sup>	5	24.26	13.048	0	0.29
Intercept	19570.015	1	19570.015	10525.819	0	0.985
TREATMENT	6.23	1	6.23	3.351	0.069	0.021
GENDER	7.216	1	7.216	3.881	0.051	0.024
TREATMENT * GENDER	2.692	1	2.692	1.448	0.231	0.009
Error	297.478	160	1.859			
Total	23021	166				
Corrected Total	418.777	165				

Dependent Variable: SATTOTAL

a. R Squared = .290 (Adjusted R Squared = .267)

The result of the ANOVA analysis in Table 2 revealed that there was no significant effect of VCLS on secondary school Chemistry students' acquisition of practical skills in acid-base titrations,  $F(1, 160) = 3.351$ ,  $p = 0.069$ , partial  $\eta^2 = 0.021$ . Thus, the null hypothesis that there is no significant effect of VCLS on secondary school chemistry students' acquisition of practical skills in acid-base titrations, is accepted. The acquisition of practical skills can take place with the use of a virtual laboratory just as well as with the use of the traditional method.

### **Gender**

To determine the extent to which gender (female and male) influenced secondary school chemistry students' acquisition of practical skills during acid-base titrations, the mean values of both groups are shown in Table 1, the mean value for males is 10.9355 while that of the female is 12.1058. Thus, female secondary school chemistry students' acquisition of practical skills is higher than that of their male peers. The same pattern occurred irrespective of the method used by the students to carry out the acid-base titration: VCL (male = 11.0227, female = 11.8500); TM (male = 10.7222, female = 12.4545) however, the gap is more obvious when the traditional method of titration was used than when VCL was used.

To test the hypothesis,

$H_{02}$ : There is no significant influence of gender (female and male) on secondary school chemistry students' acquisition of practical skills (observation, measuring, classification, communication, and inferring skills) during acid-base titrations.

The result of the ANOVA analysis revealed that there was no significant effect of gender on secondary school Chemistry students' acquisition of practical skills during acid-base titrations,  $F(1, 160) = 3.881$ ,  $p = 0.051$ , partial  $\eta^2 = 0.024$ .

### **Discussion**

From the findings, chemistry students acquired practical skills with the use of both VCLS and TM, and that there is no significant effect of VCLS on secondary school chemistry students' acquisition of practical skills during acid-base titrations. However, the study has been able to show that the use of virtual labs has great educational potential and with consistent use will effectively promote the acquisition of practical skills. Thus, virtual laboratories have been shown to be an appropriate tool that can be used to prepare students for practical work (Georgio et al., 2008, Dalgarno et al., 2010, Rajendran et al., 2010)

The influence of gender on achievement and acquisition of skills has been inconclusive, this study has found that there was no significant effect of gender on secondary school Chemistry students' acquisition of practical skills during acid-base titrations. This is in consonance with the findings of Olasheinde and Olatoye (2014) and Raimi (2010) who also found that gender is not a significant factor in the academic performance of students.

### **Implications of Findings**

The findings of this study imply that the use of virtual laboratories can be incorporated into the teaching and learning of practical chemistry at senior secondary schools. This would enable the students to be exposed to chemistry practical without the fear of interactions with dangerous chemicals thereby generating interest in practical activities in the students, which can foster a good and positive attitude towards chemistry. Also, the use of a virtual laboratory is recommended to lessen the cost of operating a conventional chemistry laboratory. 'Wastage' of chemicals is reduced, and students can practice as many times as required for mastery. This enhances learning and makes teaching easier for the teacher as well. In addition, the present technological age, which is an impetus for secondary school students to learn fast using computers is also a way of enabling interest in the students to accept learning chemistry.

### **Conclusion**

The use of a virtual lab, even though, it cannot deliver the full practical experiences has positive effects on the acquisition of practical skills for volumetric work in acid-base titrations, which can be applied to other chemistry practical activities. The use of a virtual lab will also make students get familiar easily with the names and functions of the apparatus and equipment that are used in the conventional laboratory. There is also a tendency for them to remember the procedures for carrying out the practical activities as well. Thus, the use of the virtual lab will promote students' acquisition of practical skills.

## Recommendations

It is highly recommended that Virtual Chemistry Lab Software that will be accessible to schools with reduced dependency on the use of the internet be developed and used in secondary schools to enhance the acquisition of practical skills in all science subjects.

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