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Use of Laboratory-based Pedagogies on Students' Acquisition of Science Process Skills in Chemistry

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ABSTRACT

This study investigated the effect of laboratory-based pedagogies on senior secondary school students' acquisition of science process skills in chemistry. Five research questions guided the study and five hypotheses were formulated and tested at 0.05 level of significance. The research adopted quasi-experimental, pre-test, post-test, and non-randomized control group design. Sample sizes of 63 senior secondary school two (SSSII) chemistry students from two public senior secondary schools in Okrika Local Government Area of Rivers state, Nigeria were used for the study. The students were arranged in their intact classes for the study. Chemistry achievement test (CAT) structured by the researcher, covering acid-base titrations was validated and used for collection of data. The internal consistency 0-82 for the instrument was achieved by test-retest using Cronbach coefficient alpha. Data collected was analyzed using means and standard deviation for answering the research questions and two-way analysis of covariance (ANCOVA) for testing the null hypotheses. The results showed that use of laboratory-based pedagogies for teaching and learning of science of chemistry in particular is effective in the students' acquisition of science process skills. Therefore, it was recommended that for acquisition and enhancement of science process skills in chemistry students, teachers should employ laboratory-based pedagogies.

Keywords: *laboratory, science, skills, teaching, learner and chemistry*

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INTRODUCTION

Science is comprised of processes and products of which those who engage in it must follow the pattern in order to arrive at solutions to man's numerous problems. Some of these observed problems arise from man directly while others emanate from his environment due to many other interactions within the environment. Noting that, the aim of science is to discover the happenings in the environment in other to maximize the usefulness from them in solving problems of man and his society at large. Going by this, the process of science continues and so the search in itself. A continuous process of searching and learning are necessary to demystify complexity posed by lots of nature's events. The study of nature and its events most time is not an easy one and so is referred to as complex and abstract. Chemistry is a science subject, of which most of its concepts are tagged complex, abstract and so difficult to comprehend and in other to unravel this mystery, the scientist needs to adopt experimental, practical-based methods by engaging the method of science process skills in the teaching-learning process (Abbey-Kalio & Vikoo 2019). Science process skills are means undertaken by scientists in the search and learning about natural events to arrive at solutions to man's numerous problems. Science process skills can be explained as durable and transferrable skills that are applicable to sciences and reflect the behavior of the scientists in doing his work and in the process used to solve problems of everyday life. It is therefore needful for every scientist to acquire these skills for effectiveness and efficiency in research and learning in science. The science process skills are required for learning across the sciences of which chemistry is inclusive. According to Obialor (2017), science process skills are the activities which scientists employ in carrying out scientific investigation so as to gain new knowledge. Therefore, continuous gain of knowledge about our environment and the things that are within the environment requires the scientists to engage in these activities known as science process skills. It is through engagement in these activities that the science learner is able to acquire other related necessary skills such as critical thinking skills which are also known as high order science process skills. More so, learning in science demands that the learner acquire both knowledge and skills which will further equip him to do more science and for more discoveries to solutions of man's problems. In view of the above, science process skills are abilities that defines the capabilities of scientists in mastery knowledge about the happenings of his environment and his abilities to provide explanations to such happenings. In essence, science process skills involve the engagement of both the minds and hands of the scientists in the quest to unveil knowledge about the natural world and utilize such knowledge for everyday good living.

Science education aims at preparing the learner to gain knowledge and acquire skills and use these skills to solve problems in his everyday life. This is a very important goal of science education of Nigerian Policy of Education (FRN, 2014). To this end, Espinosa, Monterola and Punzalan (2013), opined that meaningful science learning should emphasize learning based on gain of the science process skills which is essential to showcase science literacy of the learner. Padilla (2018) in his study obliged that the science teacher should focus his teaching on learner's acquisition of science process skills and for him to acquire and be able to transfer these skills in meeting his everyday life needs, become scientifically literate and be able to successfully sustain this development. According to Kuea-In et al. (2015) teachers having good knowledge of science process skills will equip them to transfer same to their students. The science laboratory is a means for both teacher and learner to acquire science process skills and knowledge of science as it gives opportunities for experimental studies. The science laboratory is absolutely necessary for every scientific activity, whether in the teaching and learning and or in doing research in science. The science laboratory is the scientists' workplace, where scientific tools and chemical/species and others used for scientific study are kept and used by the scientists. Hence, the science laboratory environment requires certain standard for accuracy and effectiveness in the level of work done by scientists. The school science laboratory is equally for teaching and learning of science and the conditions prescribed for any science laboratory should be applicable to it use as well. To develop an effective laboratory atmosphere is paramount in science research and learning (Zeindan & Jayasu, 2015; Yumusak, 2016). Hence, it will be strange for any science teacher or researcher to claim that he could effectively practice science aside the laboratory. . Laboratory learning can either take place in a space where students can carry out experiment on objects/materials of learning, phenomena and ideas, such as referred to as outdoor learning or within a well-structured and equipped place like the school and research laboratories. Though science activities can be carried both indoors and outdoors but whatever be the case the practicing atmosphere must meet the standard to ensure that good results are attainable in every science activity carried out. Sciencing or doing science implies that the learner/scientist should be in direct contact with the learning objects/materials and it is the science laboratory that creates such enabling atmosphere whereby scientific materials are gathered/assembled and organized for teaching and learning in science. The science laboratory is built to suit minds-on hands-on teaching-learning and so ideal for learning and research in science. It therefore behooves the science teacher to utilize laboratory-based pedagogies for teaching science for the learners' understanding of science concepts. No matter how abstract and difficult it may appear at first, laboratory-based methods of teaching helps the science learner to have a real feel of the world in which he lives. Therefore, the laboratory helps to erase any difficulties that may be experience by the learner in doing science. Through well-organized laboratory learning, science activities become fun, interesting and altogether arouse the science learner to learn science better instead of making it drudgery.

Laboratory-based pedagogies are practical oriented approach to teaching and learning of science. This method of teaching and learning in the laboratory encourages minds-on hands-on, student-centered, and learners' interaction with learning materials In laboratory method of teaching students have the opportunity to engage hands and minds in other to gain experience with phenomena associated with their objectives Laboratory-based learning is based on experimentation and empirical data and applicable to learning in science disciplines and engineering (https://www.esutjoe.org). The laboratory method of learning gives first-hand experience on the information about the learning material to the learner as the learner directly engages with the learning material (Abbey-Kalio & Vikoo, 2019). Because it is experimental, it gives better understanding of concepts learned and by this way, the science process skills are equally developed in the learner and not just the development of science process skills but where there are already acquired science process skills in the learner, the learner stands the change for improvement on them, meaning that the learner can apply such acquired skills in learning more science. The already acquired skills can become a method in itself for more science learning. Laboratory-based learning is explorative in that, it leaves space for students to discover on their own as students become more engaged by in the learning. Laboratory learning, other times can be very attractive method of learning especially when the laboratory environment is supported by remote and virtual laboratory, video-based experiments and some other related distance learning strategies. When the laboratory environment is provided with necessary equipment, the learning becomes fun, more attractive and enriched for the students to gain more. Laboratory-based learning is capable of developing professional competencies in the scientists being that it is inquiry-based, project-based, problem-based and has the laboratory at its center thereby engaging minds and hands of the scientist.

Laboratory-based learning offers ample of benefits to the learners, teachers, to the entire environment of the scientists and all that exist in the environment including plants animals, living and non-living things.
https://www.queensu.ca stated five objectives that may be achieved through laboratory-based learning, they are:

1. Acquisition of kills such as manipulative;
2. Concepts formation example, hypothesis;
3. Development of cognitive abilities: critical thinking, problem solving, application, analysis etc.;
4. Understanding of the nature of science: scientific enterprise and how they work, interrelationships between science and technology, and among disciplines of science etc.;
5. Development of scientific attitudes: examples: curiosity, interest, risk-taking, responsibility, collaboration, perseverance, precision etc.

Laboratory-based learning is not the same with learning in the laboratory. Learning in the laboratory is learning that is done in the conventional form which is based on following teacher's instruction and in some other case, the learner following a given manual. This is stereotype of laboratory work/practices and does not necessarily give opportunity required to the learner to apply his free access to discovery. This type of learning in laboratory does not accommodate inquiry or solving of problems or exercising of any form of science process skills and so cannot result into gain of any new knowledge and or acquisition of skills. On the other hand, the second type of laboratory-based learning which is not learning in the laboratory, can address a question or problem as the students carry out research, design and conduct experiment, collect, analyze and interpret data, draw conclusion based on the data collected, communicate same with the community of scientist and the society at large. Amongst the many things learned in the laboratory-based learning, outstandingly the acquisition of science process skills cannot be sub mounted.

Science process skills are defined as transferrable abilities, appropriate to many science disciplines and effective of the behavior of scientist. Science process skills were previously known as scientific thinking, critical thinking scientific method by science a process approach (SAPA). Padilla,(2018) in A global organization for improving science education through research). Defined science process skills as an explorative method of teaching used by the science teacher to help the science learner acquire crucial science skills for practicing of science.

Science process skills are numerous. According to Green-Osahogulu (2017) science process skills are categorized into two main groups by Science a Process Approach SAPA) and American Association of Scientists (AAS) as follows:

(a) Basic science process skills (BSPS) which includes: observing, measuring, using of numbers, and classifying. These skills can be prominent in a learner at first level of primary school.
(b) Integrated science process skills (ISPS): such as controlling of variables, formulating hypotheses, experimenting.

Collectively and with competency in these skills enables the scientists in his profession of inquiry activities and consequent solving of problems of the society. Hence, this study sought to investigate the adoption of laboratory-based pedagogies in the development of science process skills in the chemistry students in Okrika Local Government Area of Rivers State, Nigeria.

Statement of the problem

Chemistry as a science subject is experimental in nature. Evidently, the science syllabi especially at the secondary school level are consist of both theoretical and practical aspect for learning and the scenario is same for the examination at the external levels (West African Examination Council & Senior Secondary Certificate Examination). Moreover, practical activities are required to make the learners have a real feel of nature and acquire scientific skills for practice science purposes. However, it has been observed that science teachers leave out most of the practical aspects of the science teaching and even when they attempt to include practical teaching and learning, they shift it towards the end of the external examination period aiming at just the pass grades in the external examination for the students. By so doing, the students do not only have the problem of difficulty in understanding the concepts in science subjects but equally they miss the opportunity to acquire the science process skills necessary to make them better scientists and eventually to enable them become productive, creative and useful to themselves. More so, as citizens of the society that they are expected to make useful decision to effect rightful changes in accruing from their learning in science but because of lack of practical learning they may not fit properly into this role. Hence, this study adopted laboratory-based pedagogies (practical oriented teaching-learning strategies) for chemistry students' acquisition of science process skills specifically, manipulating, measuring, observing, inferring and reporting skills.

The objectives of this study are to:

1. Examine the mean achievement scores in acquisition of manipulating science process skills using demonstration teaching method and laboratory-based pedagogies.
2. Ascertain the mean achievement scores in acquisition of measuring science process skills using demonstration teaching method and laboratory-based pedagogies.
3. Assess the mean achievement scores in acquisition of observing science process skills using demonstration teaching method and laboratory-based pedagogies. Significant difference between students taught using
4. Determine the mean achievement scores in the acquisition of inferring science process skills using demonstration teaching method and laboratory-based pedagogies.
5. Examine the mean achievement scores in acquisition of reporting science process skills using demonstration teaching method and laboratory-based pedagogies.

Research questions

The following research questions guided the study:

1. What is the mean achievement scores in manipulative skills acquired by students taught using demonstration method and those taught using laboratory-based method?
2. What is the mean achievement scores in the measurement skills acquired by students taught using demonstration method and those taught using laboratory-based method?
3. What is the mean achievement scores in observation skills of students taught using demonstration method and those taught using laboratory-based method?
4. What is the mean achievement scores in inferring skills of students taught using demonstration method differ from those taught using laboratory-based method?
5. What is the mean achievement scores in reporting skills of students taught using demonstration method differ from those taught using laboratory-based method?

Hypotheses

The following hypotheses were tested at 0.05 level of significance.

HO1: There is no significant difference in the mean achievement scores in manipulating skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.
HO2: There is no significant difference in the mean achievement scores in measuring skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.
HO3: There is no significant difference in the mean achievement scores in observing skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.
HO4: There is no significant difference in the mean achievement scores in inferring skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.
HO5: There is no significant difference in the mean achievement scores in reporting skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.

METHODOLOGY

A quasi-experimental, specifically, pretest posttest non-randomized control group design was adopted for the study. The population of the study is all the senior secondary two (SS11) chemistry students in Okrika Local Government Area in Rivers State, Nigeria. The sample size of 20 students for the control group and 43 students for the experimental group in intact classes totaling 43 SSII chemistry students was used for the study. Chemistry Achievement Test (CAT) structured from acid-base titration was administered for data collection, after that it had been validated by two lecturers in the fields of science education and chemistry of the University of Port Harcourt and Ignatius Ajuru University of Education respectively. The final draft of which after effecting their observations and suggestion was satisfied as valid for measuring the variables as required in this study. Trial testing of the instrument was done on 23 chemistry students in a different public senior secondary school though from the same local government area were the study was conducted. The result from the trial test was determined using Kuder- Richardson Formula 20 of which the consistency gave 0.85. Hence, the CAT was reliable so used for both pretest and posttest for the experimental and control groups by the researcher with the help of the regular staff of the school used for the study. The experimental group was treated using laboratory-based teaching method (LB) while the control group was subjected to demonstration method of teaching (DM). The analyses of the data collected were done using mean and standard deviation for answering the research questions and analysis of covariance (ANCOVA) for testing the null hypotheses at 0.05 level of significance.

RESULTS

Tables 1, 2, 3, 4, & 5, represent the results on the research questions while (Tables 6, 7, 8, 9, & 10) represent the results of the hypotheses

Research Question 1: What is the mean achievement scores in manipulative skill acquired by students taught using demonstration method and those taught using laboratory-based method?

Table 1 shows the mean and standard deviation for experimental group taught using (LB) 7.92±1.531 pretest; 14.14±2.038 posttest and mean gain 6.22 while for control group (DM) 7.50±1.433 pretest, 11.70±2.755 posttest and mean gain 4.20 in the acquisition of manipulating skills.

Table 1: Mean and standard deviation of students taught using LB and DM in manipulating skills.

Group	N	Pretest mean	Posttest mean	SD Pretest	SD Posttest	Mean gain
Experimental	43	7.92	14.14	1.531	2.038	6.22
Control	20	7.50	11.70	1.433	2.755	4.20

Research Question 2: What is the mean achievement scores in measuring skills acquired by students taught using demonstration method and those taught using laboratory-based method?

Table 2 shows the mean and standard deviation for experimental group taught using (LB) 8.86±1.672 pretest; 15.62±2.042 posttest and mean gain 6.76 while for control group (DM) 8.15±2.581 pretest, 14.05±2.819 posttest and mean gain 5.90 in the acquisition of measuring skills.

Table 2: Mean and standard deviation of students taught using LB and DM in measuring skills.

Group	N	Pretest mean	Posttest mean	SD Pretest	SD Posttest	Mean gain
Experimental	43	8.86	15.62	1.672	2.042	6.76
Control	20	8.15	14.05	2.581	2.819	5.90

Research Question 3: What is the mean achievement scores in observing skills acquired by students taught using demonstration method and those taught using laboratory-based method?

Table 3 shows the mean and standard deviation for experimental group taught using (LB) 7.76±2.236 pretest; 15.29±1.950 posttest and mean gain 7.53 while for control group (DM) 6.90±1.518 pretest, 11.45±3.000 posttest and mean gain 4.55 in the acquisition of observing skills.

Table 3: Mean and standard deviation of students taught using LB and DM in observing skills.

Group	N	Pretest mean	Posttest mean	SD Pretest	SD Posttest	Mean gain
Experimental	43	7.76	15.29	2.236	1.950	7.53
Control	20	6.90	11.45	1.518	3.000	4.55

Research Question 4: What is the mean achievement scores in inferring skills acquired by students taught using demonstration method and those taught using laboratory-based method?

Table 4 shows the mean and standard deviation for experimental group taught using (LB) 8.38±2.701 pretest; 14.93±17.449 posttest and mean gain 6.55 while for control group (DM) 6.70±2.710 pretest, 11.25±63.892 posttest and mean gain 4.55 in the acquisition of inferring skills.

Table 4: Mean and standard deviation of students taught using LB and DM in inferring skills.

Group	N	Pretest mean	Posttest mean	SD Pretest	SD Posttest	Mean gain
Experimental	43	8.38	14.93	2.701	17.449	6.55
Control	20	6.70	11.25	2.710	63.892	4.55

Research Question 5: What is the mean achievement scores in reporting skills acquired by students taught using demonstration method and those taught using laboratory-based method?

Table 5 shows the mean and standard deviation for experimental group taught using (LB) 8.43±2.038 pretest; 14.63±1.475 posttest and mean gain 6.55 while for control group (DM) 6.80±2.375 pretest, 11.65±3.453 posttest and mean gain 4.85 in the acquisition of reporting skills.

Table 5: Mean and standard deviation of students taught using LB and DM in reporting skills.

Group	N	Pretest mean	Posttest mean	SD Pretest	SD Posttest	Mean gain
Experimental	43	8.43	14.63	2.038	1.475	6.55
Control	20	6.80	11.65	2.375	3.453	4.85

Hypothesis 1: There is no significant difference in the mean achievement scores in manipulating skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.

Table 6 shows significant effect of the achievement score of treatment group. F(2, 59) = 7.367) with p (0.001) less than 0.05 (p<0.05). Therefore, the null hypothesis that, there is no significant difference in the mean achievement score in manipulating skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy is rejected. This implies that there is a significant difference in the achievement score of experimental group being the students taught with laboratory-based pedagogy on the basis of acquisition of manipulating skills and those of control group.

Table 6: Analysis of covariance (ANCOVA) of LB and DM on manipulating skills.

Source of variation	Sum of squares	Df	Mean squares	F	Sig
Manipulating skills	0.757	1	0.757	0.141	0.708
Treatment on group	79.035	2	39.418	7.367	0.001
Error	316.506	59	5.365		
Corrected total	398.317	62			
Total	11625.000	63			

Hypothesis 2: There is no significant difference in the mean achievement scores in measuring skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy.

Table 7 shows significant effect of the achievement score of treatment group. F(2, 59) = 5.458) with p (0.007) less than 0.05 (p<0.05). Therefore, the null hypothesis that, there is no significant difference in the mean achievement score in measuring skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy is rejected. This implies that there is a significant difference in the achievement score of experimental group being the students taught with laboratory-based pedagogy on the basis of acquisition of measuring skills and those of control group.

Table 7: Analysis of covariance (ANCOVA) of LB and DM on measuring skills

Source of variation	Sum of squares	Df	Mean squares	F	Sig
Manipulating skills	2.119	1	2.119	0.390	0.535
Treatment on group	59.307	2	29.654	5.458	0.007
Error	320.526	59	5.433		
Corrected total	386.857	62			
Total	14652.000	63			

Hypothesis 3: There is no significant difference in the mean achievement scores in observing skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy. Table 8 shows significant effect of the achievement score of treatment group. F(2, 59) = 18.598) with p (0.000) less than 0.05 (p<0.05). Therefore, the null hypothesis that, there is no significant difference in the mean achievement score in observing skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy is rejected. This implies that there is a significant difference in the achievement score of experimental group being the students taught with laboratory-based pedagogy on the basis of acquisition of observing skills and those of control group.

Table 8: Analysis of covariance (ANCOVA) of LB and DM on observing skills.

Source of variation	Sum of squares	Df	Mean squares	F	Sig
Manipulating skills	32.327	1	32.327	6.374	0.14
Treatment on group	188.662	2	94.331	18.598	0.000
Error	299.254	59	5.072		
Corrected total	562.984	62			
Total	1316.000	63			

Hypothesis 4: There is no significant difference in the mean achievement scores in inferring skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy. Table 9 shows significant effect of the achievement score of treatment group. F (2, 59) = 7.089) with p (0.000) less than 0.05 (p<0.05). Therefore, the null hypothesis that, there is no significant difference in the mean achievement score in inferring skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy is rejected. This implies that there is a significant difference in the achievement score of experimental group being the students taught with laboratory-based pedagogy on the basis of acquisition of inferring skills and those of control group.

Table 9: Analysis of covariance (ANCOVA) of LB and DM on inferring skills.

Source of variation	Sum of squares	Df	Mean squares	F	Sig
Manipulating skills	136.888	1	136.888	20.539	0.000
Treatment on group	94.470	2	47.235	7.089	0.000
Error	393.224	59	6.605		
Corrected total	278.317	62			
Total	1271.000	63			

Hypothesis 5: There is no significant difference in the mean achievement scores in reporting skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy. Table 10 shows significant effect of the achievement score of treatment group. F (2, 59) = 8.480) with p (0.001) less than 0.05 (p<0.05). Therefore, the null hypothesis that, there is no significant difference in the mean achievement score reporting skills of students taught using demonstration teaching method and those taught using laboratory-based pedagogy is rejected. This implies that there is a

Table 10: Analysis of covariance (ANCOVA) of LB and DM on reporting skills.

Source of variation	Sum of squares	Df	Mean squares	F	Sig
Manipulating skills	17.837	1	17.837	3.419	0.069
Treatment on group	88.484	2	44.242	8.480	0.001
Error	307.829	59	5.217		
Corrected total	446.000	62			
Total	1221.000	63			

significant difference in the achievement score of experimental group being the students taught with laboratory-based pedagogy on the basis of acquisition of reporting skills and those of control group.

DISCUSSION

The results on (Tables 1-5) showed that chemistry students were better in the acquisition of science process skills of manipulating, measuring, observing, inferring and reporting respectively with the use of laboratory-based pedagogies that are practical oriented and such that promote minds-on hands-on of the learner rather than with the use of demonstration method that supports minds-on hands-on of only the teacher. This finding collaborate with the study of Salami, (2015) who in his study found that hands-on minds-on activities positively enhanced students learning. Achor et al (2018) also observed positive effect of laboratory-based pedagogies in enhancement of students' acquisition of science process skills. More so, the separate studies of Yadar and Mishra (2013) and Seyhan (2015) revealed positive achievement with the user of laboratory-based pedagogies for teaching and learning of science context.
Furthermore, results on the hypotheses stated showed significant difference between the use of laboratory-based pedagogy and demonstration method of teaching for the acquisition of science process skills, this showing harmony with the study of Okafor (2018) whose study suggested the use of innovative pedagogies to foster secondary school students acquisition of problem solving skills and basic science process skills in chemistry.

Recommendations

- Adequate equipment of the science laboratory should be ensured by the government by provision of sufficient funds into purchase of laboratory facilities and equipment.
- Damaged equipment should be immediately replace so as not to disrupt laboratory activities when it is due time for such learning.
- Science teachers should ensure that practical learning are regularly carried out in place of theoretical learning all through the academic session as they are used to in the past. Teachers should create opportunities whereby each student engages in actual practice of laboratory activities.
- School inspectors should during their visits to school insist on checking science laboratory inventory books to confirm if laboratory facilities and equipment are actually supplied and regularly put into use in the various schools as expected.

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