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Effect of Mathematics Laboratory-Based Instruction on Junior Secondary Students' Performance and Retention in Plane Geometry in Rivers State Nigeria

George, Nchelem Rosemary[1]; Edekor, Leonard Kwame[2]

[1]Department of Mathematics/Statistics, Ignatius Ajuru University of Education Port Harcourt, Nigeria
[2]Department of Mathematics and ICT, St. Francis College of Education, Hohoe, Ghana

ABSTRACT
This study was aimed to investigate the effect of Mathematics laboratory-based instruction on junior secondary students' performance and retention in plane geometry. The investigation had four research questions and four null hypotheses. The research design was quasi experimental. Intact classes were used for the study. A sample of 122 public junior secondary class two students was drawn from a population of 2,371 in Port Harcourt Local Government Area of Rivers State Nigeria. Plane Geometry Achievement Test (PGAT) was used to collect data. PGAT was validated and had a reliability index of 0.85. The experimental group was taught plane geometry using laboratory-based instruction while the control group was taught using deductive teaching method. Mean, standard deviation and z-test statistic were used for analysis. A significant level of 0.05 was used for hypotheses testing. The finding showed that students taught with laboratory-based instruction had a higher performance and retention than their control group counterpart with a statistical significant difference. The study also showed that the male students in the experimental group performed and retained higher than the female students though without a statistical significant difference. It was recommended that laboratory-based instruction should be used by teachers to teach plane geometry practically.

KEYWORDS: *Students, Laboratory, Mathematics, Performance, Retention*

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INTRODUCTION
Mathematics is an activity subject because it entails concept formation and problem-solving. Hence, the method of teaching mathematical concepts, skills and processes should not be entirely based on theoretical approaches but rather a variety of active learning approaches that involve hands-on activities and manipulation of mathematical tools. The teaching and learning of Mathematics has traditionally involved the memorization of mathematical facts devoid of mathematical process. Anyanwu (2019) posited that the most important phase of Mathematics is the Mathematics process because it is both creative and explorative. For creative or explorative skills to be developed, teaching must be based on methods that have the capacity to develop them. This may suggest why Chaugule (2008) opined that the best way to learn Mathematics is to practice it. Laboratory-based instruction is an instance of active learning scenario that helps to develop creative, inquiry, collaborative and communication skills in students. Incorporating laboratory-based instruction in the teaching of Mathematics is a modern way of teaching Mathematics to develop the skills necessary to succeed in Mathematics.

One of the principles of teaching Mathematics, is to teach for meaningful and mastery learning to take place. This principle is essential because mathematical concepts are hierarchical. Sunday, Akanmuand Fajemidagba (2019) posited that the Mathematics laboratory approach is an effective tool which the Mathematics teacher can use to improve students' performance in Mathematics and foster entrepreneurship skills. Mastering of concepts can be boosted by employing practical activities in

Mathematics using relevant and meaningful instructional mathematical tools. Secondary school instructors utilise traditional tapproaches to teach Math ideas, yet these approaches have no good influence on students' academic progress in Mathematics, which necessitates mastery of concepts prior to computation**.** The call to teach and learn Mathematics concepts via practical, explorative and experimental methods has led to a global movement which advocates the practical teaching of Mathematics using the laboratory approach. The use of Mathematics laboratory approach by teachers to teach Mathematics, transforms the teachers' role from an active narrator to a facilitator (Alshsafey&Aldosary, 2021).

Igwe (2018) defined Mathematics laboratory as a special roomthat contains teaching materials that are used to teach and develop students' performance and perception in Mathematics respectively. Olakunle (2019) defined Mathematics laboratory as a place that is rich with tools and equipment for teaching and learning Mathematics. It then implies that the Mathematics laboratory is a critical aspect of Mathematics education since the laboratory contains material resources that can be employed to teach mathematical concepts. Sidhu (2006) defined a mathematics laboratory as a location where teaching materials are kept, numbered, organised, documented, packed, unpackaged, grouped, ungrouped, arranged, re-arranged, mantled and dismantled, measured, and linked, among other things**.** The laboratory for the teaching and learning of mathematical concepts is a room that is equipped with teaching resources that are sourced for or improvised. The various ways the Mathematics laboratory teaching materials can be sourced for are by purchase of manufactured materials, donations from non-governmental organisations and collection from the immediate environment. The Mathematics laboratory is a place where anybody tries out new ideas and experiment with patterns. The materials are intended for learners to use alone and alongside their instructor to investigate the world of Mathematics, discover, learn, and build an interest in Mathematics. Sreedharal (2008) backed up this by claiming that the activities conducted in the Mathematics laboratory encourage students to love and exult in Mathematics. The activities in the Mathematics laboratory should be designed to provide youngsters hands-on experience with Mathematics rather than just to demonstrate concepts**.** The Mathematics laboratory can be in any of the form below:

1. Decentralized or classroom laboratory
2. Centralized laboratory
3. Multi-purpose laboratory and
4. Movable laboratory

Odili (2006) opined that the Mathematics laboratory can even be a corner where there is no spacious room to anchor it. This therefore makes allowance for every school to have a laboratory for Mathematics teaching and learning. The objectives of Mathematics laboratory based-instruction are to:

1. Provide Mathematics activities which arouse students' interest in the subject
2. Demystify complex theoretical mathematical concepts
3. Enhance students' performance and retention in Mathematics
4. Develop manual dexterity skills
5. Develop creative, logical and problem-solving skills

The afore-mentioned objectives of Mathematics laboratory-based instruction can only be achieved when the laboratory is functional. The functionality of the Mathematics laboratory includes the furnishing of the laboratory with the required laboratory consumables and non-consumables in the right quantity/quality and also the capability of the Mathematics teacher to incorporate the laboratory-based instruction effectively. To this end, consumables are laboratory materials that are bought or collected regularly because they are easily used up. Examples of consumables are cardboard, counters, sandpaper, markers, used calenders, cellotape, number/alphabet stencil, pencils, adhesive, duplicating papers, graph papers, grease, sand, fire extinguisher, drawing pins, plywood, clay. On the other hand, non-consumables are laboratory materials that are not bought or collected regularly because they are not easily used up. Examples of non-consumables are cutters (such as saws, blade, scissors), turners (such as screw drivers, pliers, panners, drillbits) for making holes, chisels, paint brush, vice mounted on tables, mathematical sets, geoboards, drawing boards, computers, calculators, french curves, hammer, scale balance, thermometer, windvane, plumbline, measuring equipment (tapes, beakers, rulers), chalkboards, textbooks, models of solids, abacus, slide rule, cuisenaire rods.

Technological, improvisation and maintenance skills of the Mathematics teacher also comes to play in the functionality of the laboratory. Some of the activities that students can carry out in the Mathematics laboratory include but not limited to experimenting with numbers, improvisation of geometrical models and charts, use of Mathematics softwares to solve and model mathematical facts, role modeling, use of Mathematics games, puzzles and manipulatives.

The properties, perimeter and area of plane shapes form an integral part of geometry and mensuration. Students therefore need to have sound knowledge of them because it will be employed as a springboard for further comprehension of the higher concepts. The best way to conceptualize the perimeter and area of plane shapes at the junior secondary school level is using an approach that is practical. One of the ways of teaching Mathematics for students to acquire the mathematical knowledge and skills needed to transform the global economy is the use of laboratory teaching approache (Krurumeh&Dogo, 2015).The laboratory-based instruction was therefore proffered to carry out the teaching in this study using geoboard.

Okigbo and Osuafor (2008) discovered that using a Mathematics laboratory method improved students' mathematical achievement. The usage of a Mathematics laboratory instructional strategy, according to Das (2020), is highly important in the teaching and learning of Mathematics. Musa and Bolaji (2015) found that using a Mathematics laboratory method increased the performance of both male and female students without a statistically significant difference. In a study on the effectiveness of teaching Mathematics using the Mathematics laboratory approach on student mathematical achievements in tertiary institutions, James (2016) discovered that students who were taught Mathematics using the Mathematics laboratory approach performed better than students who were not taught Mathematics with the Mathematics laboratory approach, with a statistically significant difference.

Statement of the Problem

The essence of teaching in schools is for the improvement of students' performance and retention of taught concepts. The retention of taught concept in Mathematics will for sure position students to have the capability to apply learnt mathematical concepts and skills to solve myriad of problems which arise in their daily activities. The teaching of Mathematics concepts in secondary schools has persistently revolved round the traditional methods. The use of traditional methods of teaching has made students to dwell on memorization of mathematical facts, rules, formulae and processes. The rote learning of Mathematics produces instrumental learning which is characterized by shallow learning and non-application. This may suggest why the performance of students in Mathematics has continued to remain poor. An instructional strategy such as the laboratory-based instruction which is characterized with active learning and the maxim of learning-while-doing can improve the performance of students in Mathematics. When students are actively involved in the hands-on manipulation of objects in the laboratory, it helps to clarify mathematical facts which may not have been able to, with the use of just talk and chalk. The perimeter and area of plane shapes is an essential and integral aspect of geometry. When students comprehend the basics of the concepts of perimeter and area of plane shape it will boost their learning of higher and supplementary concepts in geometry and mensuration. Geoboard is one of the manipulative that can be used to teach students the concepts of perimeter and area of plane shapes. The use of stories to explain the concept of perimeter and area has made so many students to dwell outside the box of geometrical realm. This therefore becomes a problem to the students because, dwelling outside the box of geometrical realm in a world that is filled with geometry everywhere forms a sort of stigma on the performance of the students in Mathematics. The question which arises is that: Can the use of laboratory-based instruction to teach students plane geometry improve their performance and retention? This question can only be answered hypothetically by investigating using the scientific method.

Objectives of the Study

1. Examine the impact of mathematics laboratory-based teaching on the performance of junior secondary students in plane geometry.
2. Determine whether there is a difference in performance between female and male junior secondary students who were taught plane geometry in a Mathematics laboratory setting.
3. Determine the impact of mathematics laboratory-based teaching on the retention of junior secondary students in planar geometry.
4. Determine the retention differences between female and male junior secondary students who were taught plane geometry in a Mathematics laboratory setting.

Research Questions

1. What is the difference between students who were taught plane geometry through laboratory-based teaching and those who are taught using the deductive teaching method?
2. Is there a difference in performance between female and male students who were taught plane geometry in a laboratory setting?
3. How does laboratory-based teaching affect the retention of students who learnt plane geometry?
4. Is there a difference in retention between female and male students who were taught plane geometry in a laboratory setting?

Hypotheses

H_{O1}: The performance of students taught plane geometry using laboratory-based teaching and those taught using the deductive teaching method is not significantly different.

H_{O2}: There is no significant difference in performance between female and male students who were taught plane geometry in a laboratory setting.

H_{O3}: The retention of students taught plane geometry utilising laboratory-based teaching and those taught using the deductive teaching method is not significantly different.

H_{O4}: There is no significant difference in retention between female and male students who were taught plane geometry in a laboratory setting.

Methods and Materials

The quasi experimental research design was used to carry out the study. The design presented one experimental group assigned for laboratory-based instruction and one control group assigned for deductive teaching method. In the Port Harcourt Local Government Area of Rivers State, Nigeria, 122 Junior Secondary Class Two (JSC2) pupils were chosen from a population of 2,371 JSC2 students. The sample was drawn using a multi-stage random sampling procedure. The first step involved sampling two schools from the research region; the second stage involved sampling to categorise the sampled schools as experimental or control; and the third stage involved sampling the whole study class in each sampled school.

The name of the instrument was Plane Geometry Achievement Test (PGAT). This instrument was made up of twenty multiple-choice test questions in the perimeter and area of plane shapes. Each test item had options A to D which students were to choose by circling only the correct answer. The test items were prepared using a test blue print. Each correct answer was assigned 5marks which gave a total of 100 marks for PGAT. Lesson plans were also prepared for the experimental group and the control group. The lesson plan for experimental group incorporated the laboratory-based instruction while the control group incorporated the deductive teaching method to teach the same concepts (perimeter and area of plane shapes).

PGAT was both face and content validated by three Mathematics education experts. The reliability of PGAT was ascertained using the split half method with a group of twenty students in JSC2 who did not participate in the sample cohort. The reliability coefficient obtained for PGAT was 0.85.

The experimental group and control group were given pretest of PGAT first. This was followed by a two weeks teaching sessions for both groups by the researchers. During the teaching sessions, the researchers employed the laboratory-based instruction to teach the experimental group the perimeter and area of square, rectangle and triangle using the geoboard. The use of geoboard made students in the experimental group to involve in learning-while-doing. The students in the control group were taught same topics using the deductive teaching method. A posttest of PGAT was given to the two groups after the teaching sessions to ascertain their performance. The post PGAT was reshuffled to produce a parallel test that was used for pre PGAT. After a period of two weeks a further parallel test of PGAT was produced by subjecting the posttest to a further reshuffling. This post posttest items were used to ascertain the retention of the experimental and control group students in the taught concepts. The three parallel tests which the students in both experimental and control groups wrote were collated and marked in percent. The research questions and null hypotheses were subjected to analysis using the mean, standard deviation and z-test statistical tools respectively.

Results

Research Question One: What is the difference between students who are taught plane geometry through laboratory-based teaching and those who are taught using the deductive teaching method?

Table 1: Performance of students taught plane geometry using laboratory-based instruction and those taught using the deductive teaching method

Group	N	Pretest		Posttest		Gain	
		Mean	SD	Mean	SD	Mean	SD
Laboratory-based Instruction	58	39.15	15.74	62.89	18.53	23.74	11.63
Deductive Teaching Method	64	40.83	13.32	56.36	24.05	15.53	12.57

Table 1 showed that the students in the experimental group who were taught plane geometry using the laboratory-based instruction had a performance mean gain of 23.74, SD = 11.63 while those in the control group who were taught with deductive teaching method had performance mean gain of 15.53, SD = 12.57. This indicated that the students taught with laboratory-based instruction in the experimental group had a higher performance mean gain than those taught with deductive teaching method in the control group.

Research Question Two: Is there a difference in performance between female and male students who were taught plane geometry in a laboratory setting?

Table 2: Performance of the female and the male students taught plane geometry using laboratory-based instruction

Gender	n	Pretest		Posttest		Gain	
		Mean	SD	Mean	SD	Mean	SD
Female	35	36.88	15.84	56.41	21.54	19.53	8.75
Male	23	41.64	16.69	69.37	18.10	27.73	12.44

Table 2 showedithatitheifemaleistudentsiinitheiexperimentaligroupiwhoiwereitaughtiplane geometry using the laboratory-based instruction had a performance mean gain of 19.53, SD = 8.75 while the male students who were taught same topics in the same group had performance mean gain of 27.73, SD = 12.44. This indicated that the male students of the experimental group had a higher performance mean gain than their female counterpart in the same group.

Research Question Three: How does laboratory-based teaching affect the retention of students who learnt plane geometry?

Table 3: Retention of students taught plane geometry using laboratory-based instruction and those taught using the deductive teaching method

Group	n	Posttest		Post-Posttest		Retention	
		Mean	SD	Mean	SD	Mean	SD
Laboratory-based Instruction	58	62.89	16.44	80.04	27.52	17.15	10.18
Deductive Teaching Method	64	56.36	18.35	65.81	21.14	9.45	7.32

From table 3, it is evident that the students in the experimental group who were taught plane geometry using the laboratory-based instruction had a retention mean gain of 17.15, SD = 10.18 while those in the control group who were taught with deductive teaching method had retention mean gain of 9.45, SD = 7.32. This indicated that the experimental group had a higher retent on mean gain than the control group.

Research Question Four: Is there a difference in retention between female and male students who were taught plane geometry in a laboratory setting?

Table 4: Difference in the retention of the female and the male students taught plane geometry using laboratory-based instruction

Gender	n	Posttest		Post- Posttest		Retention	
		Mean	SD	Mean	SD	Mean	SD
Female	35	56.41	16.53	72.01	19.82	15.60	9.41
Male	23	69.37	14.00	88.07	16.56	18.70	7.53

Table 4 revealed that the female students in the experimental group who were taught plane geometry using the laboratory-based instruction had a retention mean gain of 15.60, SD = 9.41 while the male students who were taught same topics in the same group had retention mean gain of 18.70, SD = 7.53. This indicated that the male students of the experimental group had a higher retention mean gain than their female counterpart in the same group.

Hypotheses

H_{O1}: The performance of students taught plane geometry using laboratory-based education and those taught using the deductive teaching approach is not significantly different.

Table 5: z-test analysis on the difference between the performance of students taught plane geometry using LBI and those taught using the DTM

Group	n	Mean	SD	df	Sig. level	z-cal	z-crit	Decision
Laboratory-based Instruction	58	23.74	11.63	120	0.05	2.14	1.96	Reject H_{O1}
Deductive Teaching Methods	64	15.53	12.57					

Table 5 showed that at df =120; sig. level =0.05, z-cal =2.14> z-crit =1.96. Since z-cal> z-crit, H_{O1} was therefore rejected. This indicated that there was a significant difference in the performance of students taught plane geometry with laboratory-based instruction in the experimental group and those taught same topics using deductive teaching method in the control group.

H_{O2}: There is no significant difference in performance between female and male students who were taught plane geometry in a laboratory setting.

Table 6: z-test analysis on the difference between the performance of female and male students taught plane geometry using the laboratory-based instruction.

Experimental Group	n	Mean	SD	df	Sig. level	z-cal	z-crit	Decision
Female	35	19.53	8.75	56	0.05	1.03	1.96	Retain H_{O2}
Male	23	27.73	12.44					

Table 6 showed that at df =56; sig. level =0.05, z-cal =1.03< z-crit =1.96. Since z-cal< z-crit, H_{O2} was therefore retained. This indicated that there was no significant difference in the performance of female and male students taught plane geometry with laboratory-based instruction in the experimental group.

H_{O3}: The retention of students taught plane geometry utilising laboratory-based teaching and those taught using the deductive teaching mehod is not significantly different.

Table 7: z-test analysis on the difference between the retention of students taught plane geometry using LBI and those taught using DTM

Group	n	Mean	SD	df	Sig. level	z-cal	z-crit	Decision
Laboratory-based Instruction	58	17.15	10.18	120	0.05	2.63	1.96	Reject H_{O3}
Deductive Teaching Methods	64	9.45	7.32					

Table 7 showed that at df =120; sig. level =0.05, z-cal =2.63 > z-crit =1.96. Since z-cal> z-crit, H_{O3} was therefore rejected. This indicated that there was a significant difference in the retent on of students taught plane geometry with laboratory-based instruction in the experimental group and those taught same topics using deductive teaching method in the control group.

H_{O4}: There is no significant difference in retention between female and male students who were taught plane geometry in a laboratory setting.

Table 8: z-test analysis on the difference between the performance of female and male students taught plane geometry using the laboratory-based instruction.

Experimental Group	n	Mean	SD	df	Sig. level	z-cal	z-crit	Decision
Female	35	15.60	9.41	56	0.05	1.81	1.96	Retain H_{O4}
Male	23	18.70	7.53					

Table 8 showed that at df =56; sig. level =0.05, z-cal =1.81< z-crit =1.96. Since z-cal< z-crit, H_{O4} was therefore retained. This indicated that there was no significant difference in the retention of female and the male students taught plane geometry with laboratory-based instruction in the experimental group.

Discussion of Findings

The finding revealed that the students in the experimental group who learnt plane geometry with the laboratory-based instruction outperformed their control group counterpart who learnt same topics using the deductive teaching method. The use of laboratory-based instruction made students to learn actively by participating in hands-on verification of the perimeter and area of pane shapes with the use of geoboard and rubber bands. The laboratory-based instruction did not give room for rote learning of the geometrical concepts. As a result, the experimental group's performance increased higher than the control group's. This conclusion is consistent with that of Etiubon and Udoh (2019) and Charles-Ogan, Onwioduokit, and Ogunkunle (2014), who reported a substantial difference in performance between students taught using the practical laboratory approach and those taught using the traditional teaching style. Nmecha (2017), on the other hand, disagreed with this conclusion. This discrepancy in outcomes might be due to the fact that the instructor who used the laboratory practical method did not properly include the instructional strategy. Male students in the experimental group who were taught plane geometry utilising Mathematics laboratory-based teaching showed better performance and retention than female students. When the findings were put to a statistical test, it was found that there was no statistically significant difference in student performance and retention by gender. This suggested that, despite the fact that male students in the experimental group fared better than female students, the laboratory method was beneficial to all gender of students. This conclusion is consistent with Okigbo and Osuafor's (2008) findings, which found no statistically significant difference in performance between male and female students taught mathematical concepts utilising laboratory-based teaching. Musa and Bolaji's (2015) findings are also in agreement with this**.**

Conclusion

In terms of performance and retention, this study found that laboratory-based teaching was more effective than deductive teaching in the teaching of plane geometry. It was also shown that there was no statistically significant difference in performance and retention between female and male students taught utilising laboratory-based teaching**.**

Recommendations

It was recommended that laboratory-based instruction should be used to teach junior secondary school students plane geometry concepts such as the perimeter and area of plane shapes because it enhanced the performance and retention of students in this investigation.

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