Efficacy of Origami Model in Proving Mensuration Theorems: Implications for Nigerian Senior Secondary Students' Achievement in Mathematics

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Abstract:-The study determined the efficacy of origami-based instructional model (OBIM) on teaching proofs of mensuration theorems: A panacea for college students' understanding of mathematical theorem. Population of the study was 2461 SSS III students in the public secondary schools in Awgu Education Zone, Enugu State, Nigeria. The study was guided by four research questions and four null hypotheses. The hypotheses were tested at 0.05 level of significance. Multi-stage sampling technique was adopted, through which 149 subjects were randomly sampled and used for the study. Mathematics Achievement Test (MAT) instrument containing essay items and developed by the researcher was used for data collection. The MAT was subjected to lecturers in mathematics Education and Measurement and Evaluation areas for face validation and its reliability formula yielded 0.79. The data collected with the MAT were analyzed using mean and standard deviation (SD) to answer the research questions while ANCOVA statistic was used to analyze the hypotheses at 0.05 level of significance. Results of the study revealed that OBIM is effective in enhancing students' understanding proofs of mensuration theorems. Before treatment there was no significant difference between experimental and control groups ($P \leq .05$) while after treatment there was significant difference between the duo in which the experimental group performed significantly higher than their counterpart in control group. Moreso, before treatment, there was significant mean difference in performance between the males and females in experimental group ($P \leq .05$), while after treatment there was no significant mean difference between the duo which means that the use of OBIM is effective in bridging the gap in gender inequality in mathematics performance. It was recommended to teachers, examination agencies (WAEC & NECO), authors of maths textbooks and curriculum developers to incorporate the use of OBIM in planning and execution of mathematics instruction especially in teaching proofs of mensuration theorems.

Keywords:- *Origami, Instructional Model, Mensuration Proofs, Theorems, Mathematics and Students.*

I. INTRODUCTION

Over the years, the Mathematics education researchers have emphasized strongly on the importance of activity-based instructional method on mathematics instruction for promoting active learning of mathematics on the part of the students (Eriyagama, 2018; Pokhrel, 2018; Unodiaku, 2018, and Daponte, 2007). Research findings on effective mathematics teaching, focuses on instruction that promote students' involvement on activity-based learning, reported that activity-based learning is more suitable than the other teaching methods. It is observed that mathematics learning through activities is helpful for learning mathematics as well as all-round development of students (Pokhrel, 2018). Moreso, locally, National Policy on Education (NPE),FRN (Rev. 2013), demands that in order to fully realize the goals of education in Nigeria and gain from its contribution to the national economy, government shall take necessary measures to ensure that teaching shall be practical, activity-based, experiential and IT supported.On international sane, as could be evidenced from Sri-Lanka, primary mathematics teachers are being requested to embrace activity-based teaching methods (Eriyagama, 2018). Activity-based learning appears to be invoking in the recent time in learning science subjects/courses, especially in mathematics (Unodiaku, 2018). This is in view of the notion that philosophy of activity-based learning is based on the notion that learning can be best when it is initiated by the surrounding environment and motivated by providing optimum opportunities to learn. Origami-based instructional model approach belong to such activity-based teaching methods, because it is activity-based and using it to teach mensuration proofs will help students to understand the mensuration proofs, inspire conjecture, remember theorems, perceive reality, gain global insight into mathematics as well as gain retention of materials learnt on the subject.

The importance of proof was elusive to many students, making them less appreciative in proof writing activities which increased their difficulties in understanding and constructing valid proofs (Daguplo, 2014). Thus, for many, proofs are just some esoteric, jargon-filled technical writing that only a professional mathematician would care about (Danguplo, 2014). These assertions reveals why students failed to understand and appreciate writing proofs, thereby loosing insightful understanding of mathematical concepts, ideas, algorithms, truth and competencies. Thus, leading to poor performance of 21st century secondary school students on mathematics. This study therefore, claims that there exist instructional model approach (OBIM) that can be modelled to be used in teaching and learning proofs of mathematical theorems and formulae, especially in understanding proofs of mensuration theorems.

Statement of the problem

Poor performance of students on mathematics and mensuration aspect in particular has been linked to students' difficulty in understanding and constructing proofs of mensuration theorems. The reason being that teachers are using conventional methods/approaches in proving mathematical theorems, probably because of non-availability of new approach/method that can make mensuration proofs, practically oriented or activity-based. In view of the paucity or non-availability of approach to the proving of mensuration theorems (formulae) that can ensure active participation of students in mathematics classes that this study is undertaken to determine the efficacy of using origami-based instructional model in teaching senior secondary school students mathematics in Enugu State of Nigeria.

Aims and objectives of the study

The aim of the study is to ascertain if origami-based instructional model approach when used as teaching approach will improve students' understanding of proofs of mensuration theorems and academic performance on mathematics. The specific objectives of the study were to investigate:

i. if there is any difference in the mean mathematics performance of students exposed to the experimental treatment and those exposed to the conventional method before treatment (pretest).
ii. if there is any difference in the mean mathematics performance of students exposed to the experimental treatment and those exposed to the conventional method after treatment (posttest).
iii. if there is any difference in the mean mathematics performance of male and female students in experimental group before treatment (pretest).
iv. if there is any difference in the mean mathematics performance of male and female students in experimental group after treatment (posttest).

Research Questions

Four research questions were formulated to guide the study, they are posed as follows:

1. What is the mean difference in mathematics performance of students in experimental group and those in conventional (control) group before treatment?
2. What is the mean difference in the mathematics performance of students in experimental group and those in control group after treatment?
3. What is the mean difference in the mathematics performance of male and female students in experimental group before treatment (pretest)?
4. What is the mean difference in mathematics performance of male and female students in experimental group after treatment (posttest)?

Hypotheses

The study was guided by the following null hypotheses. The hypotheses were tested at P ≤ .05 level of significance.

HO_1: There is no significant difference in mathematics performance of students exposed to experimental treatment and those exposed to the conventional method before treatment.

HO_2: There is no significant difference in mathematics performance of students in experimental group and those in control group after treatment.

HO_3: There is no significant difference in mathematics performance of male and female students in experimental group before treatment (pretest).

HO_4: There is no significant difference in mathematics performance of male and female students in experimental group after treatment (posttest).

II. MATERIALS AND EXPERIMENTAL PROCEDURE

Materials used in the experiment: Cardboard sheets, pencil, protractor, scissors, celotape and liquid gum.

Lesson Plan: Lesson plan was used in teaching both the experimental and conventional groups, while origami-based instructional model approach (OBIM) was used in teaching the experimental group only in addition to the lesson plan.

Experimental procedure

The procedure adopted in the procedure was the art of paper cutting and folding approach. Teaching and evaluation of the subjects were used in both experimental and control groups so as to normalize any pre-existing difference in mathematics achievement of subjects in both groups. The mathematics achievement test (MAT) was administered to both groups as a pre-test and the result was used as covariate measure. The teachers that taught both groups were trained by the researcher so as to control the teacher quality variable. The experimental group was taught by their regular class teacher using OBIM and lesson plan. The conventional (control) group was taught by their own teachers without any advance organizer but the same unit: Verifying mensuration theorem: surface area of a cylinder = $2\pi r(h + r)$, based on national curriculum on mathematics for senior secondary schools (FME, 2015) for three weeks using two contacts of 2½ hours each week. The experimental procedure was carried out taking the following steps:

Steps 1: Spread the cardboard sheet on a table and hold it firmly round the tablewith paper tape (see fig. 1 below).

Step 2: Use ruler and pencil to draw rectangle(s) of suitable sizes of your choice as in fig. 1 of rectangles ABCD and PQRS. These are rectangles of different heights and widths.

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Note: One only is required for the experiment.

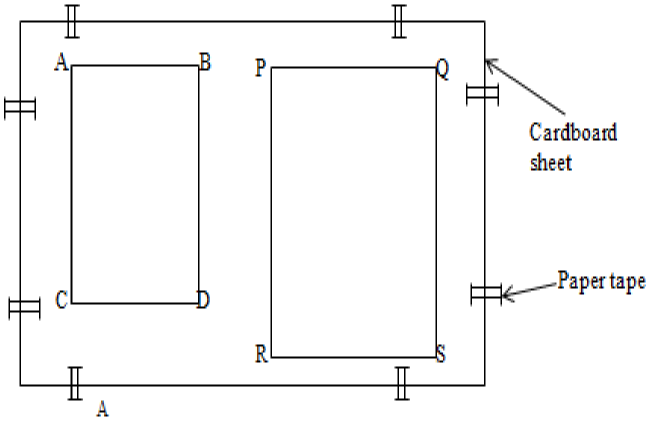

Fig. 1: Cardboard sheets ABCD and PQRS of different sizes drawn on a large rectangular cardboard sheet spread on a table

Step 3: Use scissors to cut-out the rectangle end-to-end and roll each of the rectangles to form curved surfaces (see figs. 2 (a) and (b) below).

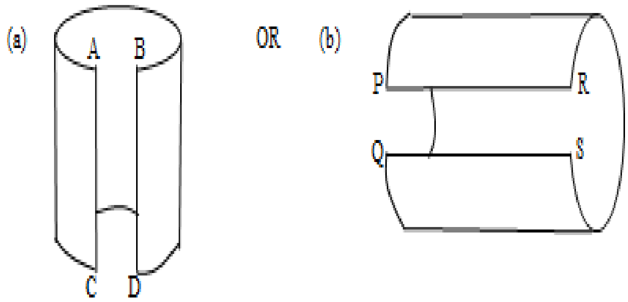

Fig. 2: Rolled cut-out of rectangles ABCD and PQRS to form a curved surface.

Step 4: Join the width (Fig. 2a) or length (Fig. 2b) end-to-end and hold them firmly with gum or celotape forming cylinder without covers (see Figs. 3a and b below).

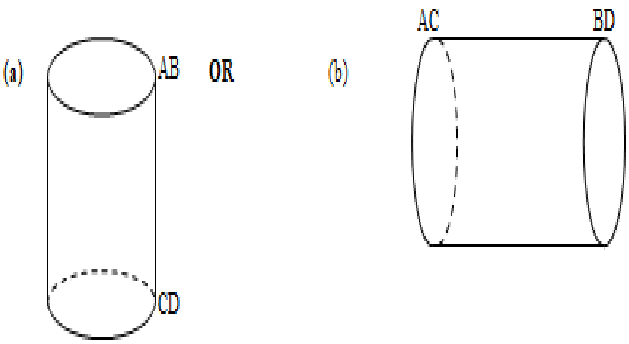

Fig. 3: Joined curved surfaces ofFigs. 2(a) and (b) above to form cylinders without covers

Step 5: Place the cylinders on another cardboard sheet (see fig. 4) gently and use pencil to draw circles around each mouth of the cylinders. Thereafter, cut-out the circle with a pair of scissors. Repeat the process using the same cardboard sheet, thereby producing identical top and bottom covers of each cylinder (see fig. 4(a) and (b) below).

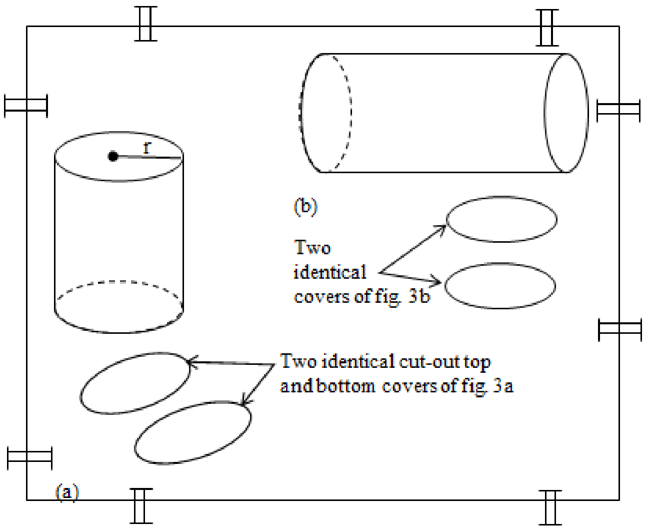

Fig. 4: from the remaining cardboard sheet on the table, cut-out two each of identical top and bottom covers of cylinders ABCD and PQRS.

Step 6: Use the liquid gum to fix the cut-out top and bottom covers of the respective cylinders to produce solid shapes of cylinders with top and bottom covers (see fig. 5 below).

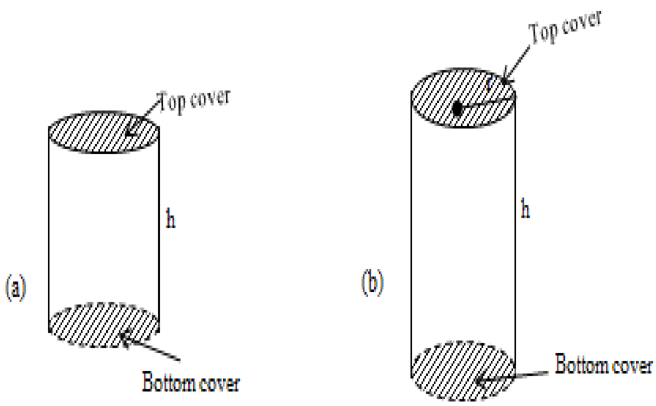

Fig. 5: Covering the top and bottom of the cylinders with its respective cut-out top and bottom covers forming solid shapes of cylinders

Step 7: Remove the top and bottom covers of the solid cylinder of fig. 5(a) in fig. 6(a) below use scissors to gently cut it to get a curved surface of a cylinder (see fig. 6(a) and (b) below).

Next, stretch fully the curved surface of the cylinder to get a rectangle fig. 6(c).

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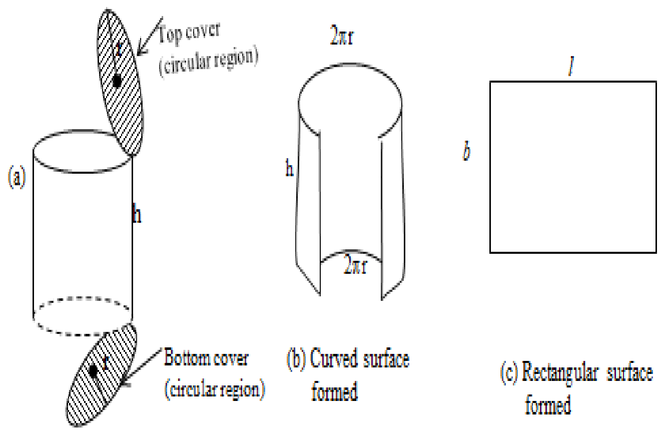

Fig. 6: Removing top and bottom covers of a solid cylinder, cutting the cylinder to form a curved surface and flattening the curved surface to obtain a rectangular surface

Similar procedures in fig. 5(a) above can be carried out in fig. 5(b) also.
Suppose we represent curved surface area of cylinder with "C" length = l, breath = b, height = h, and area of rectangle = A

$\therefore A = l \times b = lb = C$

Area of a circular base = πr^2

From fig. 6(b) and (c), students can see that:

Area of rectangle = curved surface area of cylinder (c)

i.e. $lb = 2\pi rh = C$

$\therefore C = 2\pi rh$

Total surface area of cylinder = curved surface area (C) + area of circular bottom cover + area of circular top cover

$= 2\pi rh + \pi r^2 + \pi r^2$

$= 2\pi rh + 2\pi r^2$ or $2\pi r\ (h + r)$ (by factorization)QED

Note: Students were told to determine the actual total surface area of the height and diameter of the solid cylinder each produced. The measured the heights and diameters of the solid cylinders they produced and divided the measurement of the obtained diameter of the circular top/bottom to 2 to get the radius. They therefore substituted the values of the height and radius in the formula obtained the total surface area of the cylinder.

Observations

1) Flat pieces of cardboard sheets can be transformed into origami models and used to gain insightful learning of the structure of formula for finding the total surface area of a cylinder.
2) The base and top covers of cylinder are congruent circular regions.
3) A rectangular region can be modeled to form a curved surface area of a cylinder.
4) The breath of the rectangle can become the height of the cylinder OR the length of the rectangle can be taken to be the height of the cylinder.
5) The length of the rectangle can become a circumference of the base of the cylinder OR the breath of the rectangle can be taken to be the circumference of the base of the cylinder.
6) Area of rectangle = curved surface area of the cylinder (C).
7) Irrespective of heights or sizes of rectangles, they yield similar results.

III. METHODOLOGY

This study adopted the pretest-posttest non-equivalent quasi-experimental intact class research design. The design was $2 \times 1 \times 2$ factorial. One experimental group and one control group were presented. Experimental group was taught with lesson plan on mensuration developed from the National Mathematics Curriculum for senior secondary schools, Science and Technology (2013). The study was carried out in Awgu Education Zone of Enugu State. The population of the study consisted of 2461 SSS III students in the 47 government owned Secondary Schools in the zone.

The study adopted multi-stage sampling technique. First stage involved using simple random sampling technique to sample 4 schools out of the 147 schools. The next stage involved using simple random sampling technique to sample one intact class from each of the 4 schools. This gave a total sample of 149 students composed of 84 males and 63 females used for the study. Thereafter, simple random sampling technique was used in assigning the subjects to experimental and control groups, which yielded 89 for experimental and 58 for control.

The research instrument used for data collection was Mathematics Achievement Test (MAT). The MAT contains 17 essay items used for the study. The MAT instrument was face validated by experts and thereafter it was trial tested using one intact class of SSS III students in a co-educational school that did not take part in the main study. The reliability estimate of the MAT was measured using test-retest method which yielded reliability index of 0.78. Mean and standard deviation (SD) were used in answering the research questions while research hypotheses were tested using Analysis of Covariance (ANCOVA) statistic at $P \leq .05$ level of significance.

IV. RESULTS

The result of the study were presented in accordance with the research questions raised and the null hypotheses formulated.

Research Question One:

Research questiona one and two were answered using Table 1 below:

Table 1:Descriptive statistics of Experimental group (those taught with OBIM) and Control Group (those taught with conventional method) in pretest and posttest.

Group	N	Pretest (Before treatment)		Posttest (After treatment)		Mean gain scores
		Mean	SD	Mean	SD	
Experimental (OBIM)	89	7.04	1.003	12.68	0.9401	5.64
Conventional (Control)	58	6.89	0.9017	6.63	2.3003	0.26
Mean Difference		0.15		6.05		

Table 1 shows that the pretest mean score of experimental group was 7.04 with SD of 1.003 while that of control group was 6.89 with SD of 0.9017 and mean difference of 0.15 in favour of the experimental group. This mean difference of 0.15 indicates that both groups share almost equal strength in mathematical ability before the experiment commenced (pretest). Moreso, the table shows that in the posttest, experimental group had a mean score of 12.68 with SD of 0.9401 while the control group had a mean score of 6.63 with SD of 2.3003 and mean difference of 6.05 in favour of experimental group. Subjects in experimental group achieved higher posttest than in the pretest, which shows that there was positive teaching and learning. However, subjects in control group declined in the achievement after posttest, showing lack of improvement in academic performance due to poor teaching and learning. The experimental group recorded high mean and gain score of 5.64 in favour of posttest while control group recorded a decline mean gain of 0.26 in favour of pretest. The mean differences between the experimental group and control group in pretest was 0.15 and 6.05 in posttest (after treatment). The high mean gain score of 5.64 and mean difference of 6.05 in favour of experimental group in posttest clearly indicate that the new method (OBIM) used in the experiment is effective in mathematics instruction, especially in geometry.

Research Question Three: What is the mean difference in the mathematics performance of male and female students in experimental group before treatment (pretest)?

Research Question Four: What is the mean difference in mathematics performance of male and female students in experimental group after treatment (posttest)
Research questions three and four were answered using Table 2 below.

Table 2:Descriptive statistics of male and female subjects in Experimental group before (pretest) and after (posttest) treatment.

Experimental Group (Gender)	N	Pretest (Before treatment)		Posttest (After treatment)		Mean gain scores
		Mean ($\bar{X}$)	SD	Mean ($\bar{X}$)	SD	
Male	84	3.87	1.4201	4.77	2.101	0.90
Female	63	3.99	1.4003	3.83	2.263	0.16
Mean Difference		0.12		0.94		

Table 2 above shows that the pretest mean score of males in Experimental group before treatment was 3.87 with SD of 1.4201 while that of females was 3.99 with SD of 1.4003 and mean difference of 0.12 in favour of females. These results suggest that both groups shared almost equal strength in mathematics before they were exposed to the treatment. In the posttest (after treatment), the mean score of males was 4.77 with SD of 2.101 while that of females was 3.83 with SD of 2.263 and mean difference of 0.94 in favour of males. After treatment (posttest), the males achieved higher with a record of mean gain score of 0.90 while the females performed lower after treatment (posttest) than in pretest with mean reduction of 0.16. Moreso, the males recorded lower SD (2.101) compared with females with a record of 2.263 in SD, showing that there were few or no extreme scores obtained by males than females in posttest. The mean gain scores of 0.90 and 0.16 obtained by males and females respectively shows that males are more positively responsive to the experimental treatment than their female counterpart.

Hypothesis One: There is no significant difference in mathematics performance of students exposed to the treatment and those exposed to the conventional method before treatment.

Table 3:Results of independent t-test on the performance of Experimental and Control groups before treatment (pretest)

Group	N	Mean	SD	df	$t_{cal.}$	$t_{crit.}$	P≤ .05	Decision
Experimental (OBIM)	89	7.04	1.003	145	0.923	1.96	0.000	NS*
Conventional (Control)	58	6.89	0.9017					

NS* = not significant at p ≤ .05

Table 3 show the independent t-test statistic result of students in experimental and control groups. The results showed that the t-calculated value was 0.923 while t-critical value was found to be 1.96 (i.e. $t_{cal.}$ = 0.923 <$t_{crit.}$ = 1.96). Hence, the null hypothesis which stated that there is no significant difference between the mean performance of subjects in experimental group and those in control group was not rejected. That means the initial mean difference in performance (before they were exposed to the treatment) was not statistically significant at $p \leq .05$. This shows that at the onset the two groups were sharing equal strength in mathematics performance before those in experimental group were exposed to the treatment.

Hypotheses Two: There is no significant difference in mathematics performance of students in Experimental group and those in Control group after treatment (posttest).

Table 4:Results of independent t-test on the performance of Experimental and Control groups after treatment (posttest)

Group	N	Mean	SD	df	$t_{cal.}$	$t_{crit.}$	P≤ .05	Decision
Experimental (OBIM)	89	12.68	0.9401	145	6.905	1.96	0.000	S*
Conventional (Control)	58	6.63	2.3003					

S* = significant at $p \leq .05$

Table 4 shows the independent t-test statistic result of students in experimental and control groups after treatment to the experimental group (posttest). The results shows that the t-calculated value was 6.905 while t-critical value was found to be 1.96 (i.e. $t_{cal.} = 6.905 > t_{crit.} = 1.96$). Hence, the null hypothesis which stated that there is no significant difference in mathematics performance of students in experimental group and those in control group after treatment, was rejected. That means the mean difference in performance between the control group and students in experimental group after the student in experimental group have been exposed to the treatment, was found to be statistically significant ($p \leq .05$) This means the significant difference in the posttest could be accounted for by the improved performance of experimental group resulting from the use of OBIM.

Hypotheses Three: There is no significant difference in mathematics performance of male and female students in experimental group before treatment (pretest).

Table 5:Results of independent t-test on the performance of male and female students in Experimental groups before treatment (pretest)

Experimental Group	N	$\bar{X}$	SD	df	$t_{cal.\ Val}$	$T_{crit.\ Val}$	P≤ .05	Decision
Male	84	3.87	1.4003	145	2.784	1.96	0.000	S*
Female	63	3.99	1.4201					

S* = significant at $p \leq .05$

Table 5 shows the independent t-test statistic result of male and female students in Experimental group before treatment (pretest). The result shows that t-calculated value was 2.784 while t-critical value was found to be 1.96 ($t_{cal.Val} = 2.784 > t_{crit.Val} = 1.96$). Hence, the null hypothesis which stated that there is no significant difference in mathematics performance of male and female students in Experimental group before treatment (pretest) was rejected. That means the observed mean difference in performance of male and female students in experimental group before treatment, was found to be statistically significantly different.

Hypotheses Four: There is no significant difference in mathematics performance of male and female students in experimental group after treatment (posttest).

Table 6:Results of independent t-test on the performance of male and female students in Experimental groups after treatment (posttest)

Experimental Group	N	Mean	SD	df	$t_{cal.}$	$T_{crit.}$	P≤ .05	Decision
Male	84	4.77	2.101	145	0.645	1.96	0.000	NS*
Female	**63**	**3.83**	**2.263**					

NS* = not significant at $p \leq .05$

Table 6 shows the independent t-test statistic result of male and female students in Experimental group after treatment (posttest). The result shows that the t-calculated value was 0.645 while t-crit. value was found to be 1.96 (i.e$t_{cal.} = 0.645 < t_{crit.} = 1.96$). Hence, the null hypothesis which stated that there is no significant difference in mathematics performance of male and female students in experimental group after treatment (posttest) was uphold. That means the observed mean difference in performance of male and female students in experimental group after treatment was found to be statistically not significantly different.

V. SUMMARY OF THE FINDINGS

1. Before treatment (pretest), students exposed to the experimental treatment outperformed their counterpart exposed to the conventional method with a mean difference of 0.15 in favour of those in experimental group. This mean difference of 0.15 was tested and found not statistically significant ($P \leq .05$).
2. After treatment (posttest), a mean difference of 6.05 was obtained between the experimental group and the control group. This mean difference was tested for statistically

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significant difference and found to be statistically significant (P ≤ .05).

3. In experimental group, before treatment (pretest), the females performed better than males with a mean difference of 0.12 in favour of the females. This mean difference was tested for significant difference and found statistically significantly different (P ≤ .05).
4. In experimental group, after treatment (posttest), the males performed better than females with a mean difference of 0.94 in favour of males. This mean difference was further subjected to statistical test for significance and was found statistically not significantly different (P ≤ .05).

VI. DECISION

Researcher did not presume that he controlled all the extraneous variables in the study strictly. This is because, students in the control group (exposed to conventional method) could possibly have interacted with their counterpart in the experimental group (those exposed to the treatment) and shared experiences of the research process as natural to their age bracket. In pretest (before treatment), the mean score of those in conventional group with mean difference of 0.15 in favour of those in experimental group. At the posttest (after treatment) as shown in table 6, the experimental group still gained higher mean score than the control group, with mean difference of 6.05 in favour of experimental group. This higher mean score of 6.05 in posttest gains 0.15 in pretest could be attributed to after school interaction of students in experimental and control group as well as effectiveness of the experimental treatment.

Research question one sought to determine the mean difference in mathematics performance of students in experimental group and control group before treatment. Before they were exposed to the treatment, students in experimental group outperformed their counterpart exposed to conventional method, though with a negligible mean difference of 0.15. This mean difference of 0.15 appears to suggest that initially the difference in performance between the experimental group and control group was as a result of chance factor.

Research question two sough to determine the mean difference in mathematics performance of students in experimental group and control group after treatment. After the students in experimental groups were exposed to the treatment, a high mean gain difference of 6.05 was obtained in favour of students in experimental group. This finding clearly showed that OBIM is effective in enhancing teaching and learning proofs of mensuration theorems among college students. this finding supports the demands of Blogspot (2018) and Samanta& King (2018), that activity-based method should be used in teaching mathematics, because activity-based method makes teaching of mathematics practical and experiential (FRN, 2013).

In research question three one sought to find out the mean difference in mathematics performance of male and female students in experimental group before treatment (pretest). The pretest result of students in experimental group showed that females performed better than their male counterpart. Although, the mean difference of 0.12 was found in favour of females and was tested for significance, yet it was not to be statistically significantly different (P ≤ .05).This female superiority in mathematics test on the pretest of the experimental subjects was supported by earlier reports that females performed better than males in mathematics tests (Agwagah, 1993; Hydea&Merzb, 2009; and Unodiaku, 2015).

Research question four sought to find out the mean difference in the mathematics performance of male and female students in experimental group after treatment (posttest). The posttest result showed that males performed better than females. This report corroborates earlier reports that boys performed better than girls in mathematics achievement test (Asante, 2010; Olasunde&Olaleye, 2010; and Unodiaku, 2018).

RECOMMENDATIONS/SUGGESTIONS

Based on the findings of the study, the researcher made the following recommendations and suggestions:

1. The result of the study revealed that origami-based instructional model is effective in making student comprehend proofs of mensuration theorems; and providing equal learning opportunities as no significant difference between the performance of males and females was found. It is recommended to teachers to adopt and adopt origami-based instructional model in teaching students mensuration proofs.
2. It is recommended to examination agencies such as WAEC and NECO to develop and incorporate questions based on practical activities in assessing students on proving mensuration theorems.
3. It is suggested that Education Agencies in collaboration with government (local, state and federal) should provide sponsorship opportunities for mathematics teachers to be trained in using OBIM to teach mensuration proofs.
4. It is recommended to authors of senior secondary school mathematics textbooks to include OBIM approach of proving mensuration theorem while writing Senior Secondary School Mathematics textbooks

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