Effects of Jigsaw IV Cooperative Learning Strategy (J4CLS) on Academic Performance of Secondary School Students in Geometry

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Abstract: *This study is an attempt to solve the persistent poor performance of students in geometry in senior secondary schools in Kaduna State, Nigeria. The study was guided by two research questions and two hypotheses. The quasi experimental research design involving a pretest and posttest was used. The population of the study comprised of 4624 senior secondary school year two (SS2) students of the public secondary schools in Zaria Educational Zone. Two coeducation schools were selected by the simple random sampling as the schools sampled for the study. The sample of students for the study comprised of 144 students from two schools from intact classes (Experimental = 72 and Control = 72). The Geometry Performance Test (GPT) was used as instrument for collecting data. The research questions were answered using descriptive statistics while the research hypotheses were analyzed by the t-test statistics at $P \leq 0.05$ level of significance with the aid of the Statistical Packages for Social Sciences (SPSS version 21). The study revealed a significant difference in performance in favour of students exposed to the J4CLS. With regard to gender performance, no significance difference was found. The study concludes that the J4CLS is gender friendly and effective in the teaching and learning of geometry. Based on these findings, it was recommended that teachers should employ the J4CLS in the teaching of geometry in senior secondary schools to enhance students' performance in geometry. Also, workshops and seminars for mathematics and science based teachers should be organized by the Ministry of Education for each Education Zone in Kaduna State on the use of the J4CLS in classrooms.*

Keywords: *Academic performance, Cooperative Learning, Geometry*

I. INTRODUCTION

Geometry is a branch of mathematics that is concerned with the properties and relations of points, lines, surfaces, solids, and higher dimensional analogues. It is the branch of mathematics concerned with the shape of individual objects, spatial relationships among various objects, and the properties of surrounding space [1]. Geometry is found everywhere: in art, architecture, engineering, robotics, land surveys, astronomy, sculptures, space, nature, sports, machines, cars and much more and hence, tagged the bedrock of engineering and technological development [2].

The study of geometry is very important because it has everyday application and can help students in the development of aesthetics and inductive skill. Further, geometry has been shown to facilitate the development of skills of visualization, critical thinking, intuition, perspective, problem-solving, conjecturing, deductive reasoning, logical argument and proof [3]; [4]. The development of geometry thinking and their representation is very important in the study of geometry; this is because it is a function of spatial skills which follows from spatial sense, spatial perception, spatial insight, spatial visualization and spatial orientation [5] [6]. [7] put up a case for the importance of geometry in a lecture at the University of Cambridge; he said:

"the wonderful thing was that for those who saw education as taking you nearer God, geometry was something of a royal road. And for those who saw education as a security against the arbitrary and non-rational excesses of occult and mystical fantasies, or the arbitrarity of religion, geometry was the surest buttress…. Since the ancient Greeks geometry has been the paradigm of truth and ordered knowledge, of clear thinking and the rigour of absolute precision of thought." (p29, 31)

Even though geometry has these laudable potentials and much more, it is one aspect of mathematics that students have been reported to dread or shy away from and consequently have become weak at it. The difficulty associated with the teaching and learning of geometry has been indicted to contribute to the mass failure of students in mathematics [2]. The problem of learning and teaching geometry in secondary schools has become an issue globally. Generally, studies have consistently reported low performance of students in mathematics; but geometry is the core difficult area in mathematics, which contributes to this malady. It has been observed that students are generally weak in geometry, dreaded this aspect of mathematics and only very few candidates attempt questions on geometry over the years [8] [2], [9].

The problems identified in the teaching and learning of geometry at the secondary school level include the following:

1. weak teachers' background in geometry [9].
2. weak foundation of students in geometry from primary school mathematics [2].
3. poor preparation of teachers due to high workload [2]
4. lack of interest among students for geometry [2],
5. poor understanding of geometry concepts and problem solving skills [9],
6. lack of proper guidance to construction and proof of geometric figures,
7. anxiety for geometrical figures due to perceived difficulty [9], and
8. poor methods and approaches to teaching among others [10].

This study addressed specifically the methodology in the teaching and learning of geometry. The study also facilitated students understanding of geometrical concepts and ability to prove theorems at the secondary school level.

Objectives of the Study

The objectives of the study are to:

i. investigate the effect of J4CLS on students' academic performance in geometry.
ii. compare the performance of male and female students when exposed to the J4CLS.

Research Questions

The following research questions were formulated as guide to the study:

i. What is the difference in mean performance scores of students taught geometry using the J4CLS and those taught by the lecture method?
ii. What is the difference in mean performance scores of male and female students taught geometry using the J4CLS?

Null Hypotheses

The following null hypotheses were tested at $P \leq 0.05$ level of significance in the study.

H_{01}: There is no significant difference in the mean performance scores of students taught geometry using the J4CLS and those taught using the lecture method.

H_{02}: There is no significant difference in the mean performance scores of male and female students taught geometry using the J4CLS.

II. Literature

Cooperative learning

Cooperative learning (CL) refers to instructional methods in which the teachers organizes students into small groups, who then work together to help one another learn academic content [11]. It is a mode of learning in which students of different levels of ability work together in small groups to achieve a purpose [12].

[13 demonstrated when cooperative learning is desirable. She said:

> Whenever problem solving is desired, whenever divergent thinking or creativity is desired, whenever quality of performance is expected, whenever the task is complex, when the learning goals are highly important, and when the social development of learners is one of the major instructional goals….
>
> When an instructor wishes to promote positive interaction among learners, a facilitative learning climate, a wide range of cognitive and affective outcomes, and positive relations between themselves and the learners …(p.1)

Cooperative learning is a process in which students create, analyze and apply concepts. Students learn life-long concepts that will be useful both inside and outside the school. They are required to work as a team, combining their knowledge and social skills. Students are often placed in heterogeneous groups and asked to accomplish a common goal. Each team member is assigned part of the content to be learnt and is not only responsible for their learning, but the other group members' learning as well. Students work until each group member successfully understands all concepts and then the assignment is completed.

According to [14], in the cooperative learning, students work together as a team to maximize the academic success of all the team members. The failure of even a single member can compromise the success of the entire team. Thus, to evaluate the functioning of the team reliably, it is necessary to consider both the performance of the individual team members and the interactions among them.

In the cooperative learning strategy (CLS) small teams each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject matter. It is a learning environment that allows active participation of students in the learning process, makes it possible for the students to have control over their learning and this leads to improvement in students' learning and retention as to both the developmental and cognitive theoretical bases thereby prevailing classroom climate of cooperation [15]. Each member of a team is responsible for not only learning what is taught but also for helping teammates learn, thus creating an atmosphere of achievement. Students work through the assignment until all group members successfully understand and complete it. Cooperative learning environment assumes that students seek information

and understanding through active mental search with each group mirroring the make-up of the class in terms of ability, background and gender.

Jigsaw IV Cooperative Learning Strategy (J4CLS)

Jigsaw is a cooperative learning technique that was developed by Elliot Aronson and his colleagues in 1978. The jigsaw technique was created with the goals of reducing conflict, enhancing positive educational outcomes and to help students realize they are essential components of a whole and encourages cooperation in a learning environment.

In science education, the Jigsaw method and its variants are reported to be used in classes more often than other collaborative learning methods, especially in biology, chemistry, physics, Mathematics and the Earth sciences. This is because the Jigsaw method is considered to enhance cooperative learning by making each student focus on a particular topic [16]. Jigsaw is a cooperative learning strategy in which everyone becomes an expert and shares learning so that eventually all group members know the content.

There are currently six types of Jigsaw cooperative learning strategies available for teachers to use in the classroom [16]. They are: Jigsaw I [17], Jigsaw II [18], Jigsaw III [19], Jigsaw IV [20], Reversed Jigsaw [21], and the Subject Jigsaw [22].

The Jigsaw IV includes three new features: an introduction, quizzes, and re-teaching of material after individual assessment which makes it better than Jigsaw I, II and III [16].

Gender Differences in Geometry Performance

Globally, there have been debates on students' performances in mathematics with respect to gender, which has continued to be of interest and inconclusive [23]. Studies such as [24], [9], and [25] observed that male students outperform their female counterpart in mathematics. The greatest difference in performance between male and female students was exhibited in mathematical reasoning and geometry; this follows because male students display greater confidence in their mathematics skills, which is a strong predictor of mathematics performance [26].

Thorough studies such as [27] and [28] reported that gender differences among male and female is closing and both male and female perform similarly. This view is supported by [29] and [6] who asserted that there is no significant statistical difference between the performance of male and female students in mathematics worldwide. Yet, gender differences in mathematics and science continues to exist in some countries [30]. Cases where female dominate their male counterparts in terms of performance in mathematics are rare. Many factors (not fully discussed in this study) given by researchers reported to be responsible for the dominance of male in mathematics includes gender imbalance, task difficulty, cognitive competence, perceived negative attitude toward females students by their teacher among others.

In the study of geometry, the same situation and result holds in terms of gender achievement and performance. Studies such as [31] and [32], submitted that male students performed better than their female counterpart did by exhibiting better spatial abilities. Other studies like [33] and [4] found no significant difference in the performance of students in geometry and hence their mathematical performance at the secondary school level. Furthermore, Freeman (2004), asserted that gender differences in mathematical reasoning have begun to decline due to more female student's enrolments in mathematics and science courses.

III. METHODOLOGY

The research design adopted for this study was the quasi-experimental research design. The design comprised two-groups, one experimental (**EG**) and the other control (**CG**). The population of the study comprised of all senior secondary school year two (SS II) students of the public schools in Zaria Educational Zone, Kaduna State. This was made up of nineteen (19) senior secondary schools with a total enrolment of four thousand, six hundred and twenty-four (4624) students. The zone has nine (9) co-educational schools, five (5) single boy's schools and five (5) single girls schools located in various settlements in two neighbouring Local Government Areas.

Four co-education schools (4) were initially selected by the simple random sampling out of the nine (9) co-education schools in Zaria Educational Zone namely: GSS Aminu, GSS Tudun Jukun, GSS Kuyanbana and GSS Dakachi. These schools were pretested on a multiple choice Geometry Performance Test (GPT) which was an instrument developed by the researchers for the study. The result obtained was subjected to the analysis of variance (ANOVA) and the Scheffe's test to determine the student's ability. The reliability of GPT was found to be 0.84 when the test-retest method was observed and the result subjected to the Pearson Product Moment Correlation.

Consequently, two schools were then selected by simple random sampling from the three schools found to have equivalent ability. They are GSS K/ Kuyanbana (taken as the experimental school) and GSS Dakachi (as the control school).

One intact class from the SS2 arm was selected by simple random method from each of these schools for the study. This was because the school administration did not allow disorganization of classes for the purpose of the study. The sample for the study which comprised 72 students (male = 40 and female = 32) for the experimental group and 72 students (male = 42 and female = 30) for the control group. Hence, the total number of students for the study was 144 (male = 82 and female = 62).

The research questions were answered using the descriptive statistics while the hypothesis was analysed by the student's t-test at $P \leq 0.05$ with the aid of the Statistical Packages for Social Sciences (SPSS version 21).

GPT was administered to the students in both groups (experimental and control) of sampled schools before treatment was started as pretest. The result obtained facilitated the placement of students into home groups of four students each coded by alphabetic letters A, B, C … and so on as presented in Table 1.

Table1: Home Group Plan

Group 1	Group 2	Group 3	…	Group 18
A1 A2	B1 B2	C1 C2	…	R1 R2
A3 A4	B3 B4	C3 C4	…	R3 R4

In each home group, a member was given a number code A1, A2, A3, or A4 etc. These numbers codes determined the Expert Group [EG] (Table 2) a student consequently belonged to. Members in respective home groups with the same number code studied a sub-topic in geometry.

Table 2: Expert Group Distribution Plan

EG 1	EG 2	EG 3	EG 4
A1, B1, C1, D1	A2, B2, C2, D2	A3, B3, C3, D3	A4, B4, C4, D4
E1, F1, G1, H1	E2, F2, G2, H2	E3, F3, G3, H3	E4, F4, G4, H4
I1, J1, K1, L1,	I2, J2, K2, L2,	I3, J3, K3, L3,	I4, J4, K4, L4,
M1, N1, …R1	M2, N2, …R2	M3, N3, …R3	M4, N4, …R4

The sub-topics were distributed according to codes (1, 2, 3 & 4). Students with the same number code were placed in the same expert group and consequently studied the sub-topic in their expert material (Table 3).

Table 3: Expert Groups and Sub-topics

Sub-topics in Geometry for Expert Groups	
A1, B1, C1, D1 … R1	Angles and Intercept
A2, B2, C2, D2 … R2	Triangles and Polygons
A3, B3, C3, D3 … R3	Circle Geometry
A4, B4, C4, D4 … R4	Loci

Upon completion of study, all students in the Expert group returned to their Home groups in line with the J4CLS procedure. After home group interactions, the posttest (GPT) was administered and individual score obtained. The male and female students were scored separately after the treatment to ascertain their relative achievement. Treatment to the experimental group lasted for 75 minutes three times a week for six weeks. In the control group, the normal school timetable for mathematics was followed for six weeks and the student were taught same concepts by the lecture method. The control group was treated with the lecture (conventional) method using GPT for both pretest and posttest.

IV. RESULTS

Research Question 1

What is the difference in mean performance scores of students taught geometry using the J4CLS and those taught by the lecture method?

Table 4: Descriptive Statistics for Performance between Experimental and Control Groups

Group	N	Mean Posttest	SD Posttest	S.Error Posttest
Experimental	72	65.72	11.564	1.363
Control	72	36.44	10.648	1.255

Table 4 presents the mean scores and standard deviation scores of the experimental and control groups respectively. The experimental group had a higher mean score of 65.72 while the control group had a mean score of 36.44. Also, the experimental group had a standard deviation score and standard error of 11.564 and 1.363 respectively. The control group had 10.648 and 1.255 as its standard deviation and standard error respectively. This implies that there is a difference in the mean and standard deviation scores of the two groups in favour of the experimental group. To find out if this observed difference is significant or not, the t-test analysis was carried out. The result was presented in Table 6.

Research Question 2

What is the difference in mean performance scores of male and female students taught geometry using the J4CLS?

Table 5: Descriptive Statistics for Performance between Male and Female Students in the Experimental Group

Group	N	Mean Posttest	SD Posttest	S. Error Posttest
Male	40	66.10	12.651	2.000
Female	32	65.25	10.223	1.807

Table 5 presented the descriptive statistics of academic performance mean scores of male and female students who learnt geometry by the Jigsaw IV cooperative learning strategy only. The result showed that the male students had a higher mean score of 66.10 and their female counterpart had a mean score of 65.25. Their respective standard deviation scores and standard error for posttest was found to be 12.651

and 2.000 for male students and 10.223 and 1.807 for the female students. Hence, there was a difference in the posttest mean scores of male and female students. This indicates that the male students did slightly better. A t-test analysis was observed in order to determine if the descriptive statistical means of the male and female student was significant. This was presented in Table 7.

Null Hypothesis 1

H_{01}: There is no significant difference in the mean performance scores of students taught geometry using the J4CLS and those taught using the lecture method.

Table 6: Independent t-test for Performance between Experimental and Control Groups

Group	N	Mean	SD	df	t-value	P-value
Experimental	72	65.72	11.564	142	14.811	0.001*
Control	72	36.44	10.648			

*Significant at P≤ 0.05

From Table 6, the t-value of 14.811 has a corresponding P-value of 0.001 at 142 degrees of freedom, which was less than P-value of 0.05 level of significance. P = 0.001 is significant hence, the null hypothesis one (H_{01}) was rejected. This meant that there was a significant difference between geometry performance of the experimental and control group. The result therefore showed that the J4CLS is more effective than the lecture method in improving students' academic performance in geometry. This was connected to the nature of the J4CLS, which is a student-centered teaching approach.

Null Hypothesis 2

H_{02}: There is no significant difference in the mean performance scores of male and female students taught geometry using the J4CLS.

Table7: Independent t-test for Performance between Male and Female Students in the Experimental Group (Posttest)

Group	N	Mean	SD	df	t-value	P-value
Male	40	66.10	12.651	70	0.308	0.759*
Female	32	65.25	10.223			

*Not Significant at P≤ 0.05

Table 7, revealed that a P-value of 0.557 was obtained from the t-value of 0.308 at 70 degrees of freedom. This value is not significant since P = 0.557 is greater than P = 0.05 level of significance. Therefore the null hypothesis two (H_{02}) was retained. This implied that there was no significant difference between geometry performance of male and female students in the experimental group when exposed to the J4CLS. The result therefore showed that the Jigsaw IV cooperative learning strategy is a gender friendly teaching methodology.

Discussions

The aim of this study was to assess the efficacy of Jigsaw IV Cooperative Learning Strategy (J4CLS) on the academic performance of secondary school students in geometry in Kaduna State, Nigeria. Four topics namely Angles and intercept, triangles and polygon, circle geometry and loci were examined in the study. The students in both the experimental and the control groups used in the study had equivalent knowledge of geometry as determined by the result of the pretest (ANOVA and Scheffe's test) administered before the treatment commenced. Therefore, the differences observed were due to treatment. The results of data on research questions null hypotheses tested are discussed as follows:

The result in Table 4 showed that there is a difference in the mean and standard deviation scores of the experimental and control groups in favour of the latter. This difference was subjected a t-test in Table 6. The Table revealed that the difference observed was significant. The students exposed to the J4CLS had a higher mean gain of 50.44 compared to those taught by the lecture method who had a mean gain of 28.39. This gain in favour of the experimental group was also observed in the groups standard deviation scores. This implied that the use of J4CLS improved students' academic performance in geometry.

This finding is in line with that of [16], [34] & [35], who found out that the J4CLS was effective in enhancing students' performance in school based subjects like mathematics. They found a significance difference in performance in favour of the experimental group. This is evidenced in the higher mean scores obtained by students in the experimental groups of their respective studies when compared to other methods of learning. Also, [36] and [10] in their separate studies found that the cooperative learning strategy is effective in the teaching and learning of geometry and mathematics; they recommended the use of cooperative learning strategy in the teaching and learning of mathematics in Nigerian schools.

The result obtained from Table 5 revealed a higher posttest mean performance score of 66.10 and standard deviation score of 12.651 for the male students compared to that of the female students who had a posttest mean performance score of 65.25 and standard deviation score of 10.223. It was observed that the male students had a slightly higher mean gain of 53.75 compared to the female students mean gain of 53.05. Consequently, this difference was subjected to the t-test analysis as shown in Table 4.

The Table revealed the observed difference was not significant. This finding is in agreement with that of [37], and [4], who reported that there was no significant gender difference in achievement when

students were exposed to the Jigsaw CLS. Further, this study confirms the findings of [28], who found no significance difference between performance of male and female students in mathematics in general. The authors concluded that this is due to a global closure in the performance of female in contrast to the dominance their male counterpart in the subject as many literatures suggests.

V. CONCLUSIONS

The study was on the effects of Jigsaw IV cooperative learning strategy on the academic performance and interest of secondary school students in geometry in Kaduna State, Nigeria. From the findings of the study, which was based on the descriptive and statistical analyses of data collected and presented in chapter four, the following conclusion was arrived at.

The J4CLS was more effective at improving geometry than the lecture method. The J4CLS has significant effect on the academic performance of students. This is evident in the higher mean performance scores obtained by students who were exposed to it. It was also observed that it is gender unbiased since male and female students perform equally well.

These findings have some important implications that will be useful for the teaching and learning of geometry and mathematics generally. For instance, Zembar and Blume (2009) opined that greater gender gap exists in performance among male and female students in mathematical reasoning and geometry which follows because male students were found to display greater confidence in their mathematics skills but the result of this study revealed the converse. Perhaps this was as a result of inappropriate methodology utilized in the teaching of mathematics. Again the performance and other measurable gender gaps observed over time among students in mathematics is gradually closing up.

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RECOMMENDATIONS

Based on the findings of the study, the following recommendations are made:

1. Teachers should employ the J4CLS in the teaching of geometry in senior secondary schools' classroom to enhance students' performance since the strategy is student-centered based. The strategy also facilitates the learning of much material in limited time which can help the teacher and students cover large portions of the school syllabus.
2. Students should be encouraged by their teachers to participate in the J4CLS because it is a result oriented strategy that has the potential of improving their interest and performance in mathematics. It also opens them up to the skill of leadership, tolerance and collaborative efforts that will be needed for success in their careers and life.
3. Workshops and seminars for mathematics and science based teacher should be organized by the Ministry of Education for each education zone on the use of the J4CLS in classroom.
4. Curriculum planners should officially make J4CLS a valid method for teaching and learning of mathematics topics like geometry in secondary schools. This will go a long way in building national harmony and team spirit in students.
5. Textbook writers should inculcate the J4CLS as a method for teaching geometry and mathematics. This will popularize and make J4CLS acceptable among teachers.

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cooperative-learning strategies on student understanding and long-term memory, student and teacher attitudes and engagement. Through the use of cooperativelearning strategies students are tasked with working collaboratively towards a shared goal. Each lesson utilizes peer to peer learning and self-discovery.Â I believe that this lack of participation is directly linked to poor academic performance in my biology classes, which also contributes to a lower rate of passing for biology students on the state biology assessment that is a requirement for high school graduation. To address this issue of participation, I completed background research on student participation within various classroom environments.