



Effects of Geogebra Instruction and Team-Based Learning Strategy on Senior Secondary School Students' Achievement in Mathematics

Adeneye Olarewaju A. Awofala^{1,*}, Nwakaego Iheoma Nwoke²

¹University of Lagos, Nigeria

²Federal College of Education, Nigeria

*Correspondence: E-mail: aawofala@unilag.edu.ng

ABSTRACT

The purpose of this study was to investigate the effects of GeoGebra instruction and Team-based learning on senior secondary school students' achievement in mathematics. The study adopted a quasi-experimental pre-test, post-test, non-equivalent control group research design. The sample consisted of 183 students (91 males and 92 females) from three intact classes of three senior secondary schools from Education District V of Lagos State, Nigeria. Simple random sampling technique was used to assign the three intact classes to experimental group I, experimental group II and the control group. Data collected were analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA). Results revealed that there was a significant main effect of treatment on students' achievement in mathematics in favour of GeoGebra instruction and team-based learning. Gender did not significantly influence students' achievement mathematics, and there was no significant interaction effect of treatment and gender on achievement in mathematics. The study concluded that the GGI and TBL experimental treatments had better effect on students' achievement in mathematics than the CLM.

ARTICLE INFO

Article History:

Submitted/Received 20 Decss 2025

First Revised 25 Jan 2025

Accepted 27 Feb 2025

First Available online 28 Feb 2025

Publication Date 01 Mar 2025

Keyword:

Conventional lecture method,
Geogebra instruction,
Mathematics achievement,
Team-based learning.

1. INTRODUCTION

An effective teacher applies innovative and creative teaching methods to teach academic concepts and meet the individual needs of students. Thus, this is not observed by teachers who stick to their preferred teaching methodology. It is important to explore evidence-informed pedagogical ideas that have the potential to expand our repertoire of knowledge in the classroom. Mathematics is a language of science and very important backbone of the humanities. The development of an ideal society mostly based on the economic and technological advancement of the society, and education at any level and in any form, demands basic knowledge of arithmetic and mathematics. Mathematics has rich potentials to afford true enjoyment to its students, however, the teaching of mathematics present numerous day to day challenges to the teachers of mathematics due to inefficient and stereotyped instructional strategy. It is most times described as dull and dry. Since mathematics is a compulsory subject to be mastered for the progression of both individual and national development, there must be other strategies that could be used to teach and learn mathematics successfully. The primary aim of developing learners' understanding of basic mathematical concept is further application to scientific ideas capable of progressively developing the nation. It is expected that the basic principles and concepts of mathematics are taught in a manner that portrays clearer understanding.

At present, mathematics is widely used in various fields and covering a wide range of activities. One of the major objectives of teaching mathematics in secondary school level is to enable individuals apply mathematical knowledge in and outside the classroom. However, it has been observed that many students are unable to apply mathematics learned in school in solving problems, which shows that, to a large extent, mathematics instructions have failed in achieving its main objective (Awofala & Lawal, 2022). This failure is also evident in the decline in the mathematics achievement in classrooms and students' poor performance in mathematics in public examinations like senior secondary certificate examinations (SSCE) and unified tertiary matriculation examinations (UTME) in Nigeria (Awofala & Lawani, 2020a). One major reasons often provided for the decline in mathematics achievement in schools is teachers' inability to apply innovative methods and instructional materials in the teaching and learning of mathematics (Adeniyi & Awofala, 2023). While there is advocacy for alternate methods of teaching mathematics, many teachers still remain stuck to the conventional lecture method (Berrett, 2012). Adopting the conventional lecture method in order to cover the syllabus does not make the mathematics fun and interesting; rather it makes the students see mathematics as abstract, which will in turn lead to low achievements. The problems that lack of innovative methods of teaching mathematics pose to the present students' achievement and future ability to apply mathematics taught in school in solving problems inside and outside the classroom call for broadening of instructional strategies.

Conventional lecture method has an undue focus on memorization and recall of facts, instead of conceptual understanding, and has failed to produce results (Adeniyi & Awofala, 2023). There is need to adopt and research into alternative methods of teaching mathematics that emphasize on conceptual understanding and application of knowledge to overcome the shortcoming of the conventional lecture method. Conventional lecture method has been identified as one of the major shortcomings in the traditional secondary education. It emphasizes the passive acquisition of knowledge, where students become passive recipients of knowledge and resort to rote learning (Berrett, 2012; Awofala *et al.*, 2013). Lecture-based instruction is a teacher-centred instruction. It dominates classroom activity with teachers doing most of the talk. The traditional classroom is characterized by directed demonstrations

and activities to previously introduced concepts. Hence, instruction is not for conceptual understanding, but rather for memorization and recalling of facts (Berrett, 2012).

In recent times, the world has experienced rapid growth of technology which involves the introduction and design of educational software. As such, different studies have been conducted on technology-assisted teaching and learning, whereby different factors have been identified for the successful integration of such technology (Islahi & Nasrin, 2019). Researchers have shown that technology is capable of assuaging the fears of students in learning mathematics if appropriately used in the classroom. Apparently, because of these concerns, different researches have been carried out on effective use of different mathematics software in facilitating teaching and learning in various parts of the world. New technologies and innovations are emerging to assist teaching and learning of mathematics, and GeoGebra is one of those innovations. GeoGebra Instructional Package is an innovative, open-source mathematics software that can be freely downloaded from www.GeoGebra.com and it works on a wide spectrum of operating system platforms. It is self-motivated mathematics software created in 2002, by Markus Hohenwarter and a team of programmers for the teaching and learning of mathematics from middle school through college to university level.

GeoGebra is one of the educational software which has been designed and investigated by some studies as to what extent its use enhances students' conceptual understanding and attitudes toward mathematics. The potential of GeoGebra as an ICT tool on students' mathematical thinking improvement was investigated and found that GeoGebra is effective, in as much as it is integrated effectively into teaching mathematics in all levels of education, from primary education up to secondary level (Bulut *et al.*, 2016). One of the researches carried out using mathematics software includes (Kesan & Caliskan, 2013) who investigated the effect of Geometer Sketchpad in learning geometry in Turkey. It is in line with the trend of the use of mathematics software in the classroom and its resultant effect on learning outcomes of students that the researchers adopt GeoGebra instruction (GGI) to teach secondary school students mathematics and ascertain its effect on their achievement in Education District V in Lagos State, Nigeria.

Cooperation is a common phenomenon among social beings whereby individuals seek outcomes, not only for his/her survival but also for the progress of his/her community. Team-based learning is the instructional use of small groups, so that students work together to maximize each other's learning (Michaelsen & Sweet, 2011). The idea is simple, class members are organized into small groups after receiving instructions from their teacher, they then work through the assignment until all the group members successfully understand and complete it. Team effort results in all participants striving for mutual benefits, so that each member gains knowledge from others' effort, bearing in mind that all group members share the same fate, that is, "sink or swim together". Individual performance is mutually facilitated by one's self and one's colleagues. This promotes more positive attitude towards the instructional experience than an individualistic method. Team-Based Learning (TBL) is defined as an active learning and small group instructional strategy that provides students with opportunities to apply conceptual knowledge through a sequence of activities that includes individual work, team work, and immediate feedback (Parmelee *et al.*, 2012). TBL was originally designed by Professor Larry Michaelsen during the 1980s, in the United States of America, for use in business schools. Michaelsen developed TBL in response to increasing class sizes, and his concern about the effectiveness of learning from lectures in large groups (Burgess *et al.*, 2014).

Team-Based Learning provides the opportunity to continue teaching in a manner that is engaging, cater for large number of students, provides immediate feedback, involves students in decision making, and promotes active small group and class discussions, and goes beyond the simple transfer of content, to the application of knowledge through conceptual and procedural problem solving (Michaelsen & Sweet, 2008; Awofala *et al.*, 2012). In recent years, Team-Based Learning has gained popularity in education as a resource-efficient, student-centred teaching pedagogy (Olabiyi & Awofala, 2019; Awofala & Lawani, 2020b), sometimes introduced as an alternative to Problem-based learning (PBL) (Awofala & Akinoso, 2024; Fatade *et al.*, 2014). Students are more likely to acquire critical thinking skills and mental cognitive strategies which include learning how to learn in a small group. Students feel proud and celebrate jointly when a group member is recognized for achievement. In a team learning situation, there is a positive interdependence among students goal achievement. Students perceive they can reach their learning goals if and only if other students in the learning group also reach their goal. It is believed that learning of mathematics is not about dispersing rules, definitions and procedures for students to memorize, but engaging students as active participants through discussions and collaboration among students.

Among other factors, gender is a recurring decimal in the currency of research engagements. Gender influences so many personal and corporate decisions in human existence such as choice of academic career and profession. Many research outcomes favour the negative influence of gender for females (Awofala & Uwajuwa, 2023; Awofala, 2011, 2008), while some are neutral (Awofala *et al.*, 2020; Awofala *et al.*, 2022; Awofala & Anyikwa, 2014; Arigbabu & Mji, 2004; Awofala, 2017). Gender differences are important and many times have become a determinant factor in crucial decisions and policies. Gender plays a major role in students' achievement especially in mathematics. Therefore, its differential achievement is expected among students. gender describes the personality traits, attributes, behavior, values, relative power, influence, roles and expectations (femininity and masculinity) that society ascribes to the two sexes on a differential basis. Therefore, gender is a psychological term and a cultural constant developed by society to differentiate between the roles, behavior, mental and emotional attributes of males and females. Favourable learning outcomes in mathematics is very vital to societal growth and development, therefore effective learning strategies such as GeoGebra instruction and team-based learning can alleviate anxiety capable of improving the learning outcomes in mathematics. The place of mathematics in human development demands that methods of teaching should be dynamic for optimum attainment of set goals and objectives.

In the Nigerian context, the paucity of research studies in the use of GeoGebra, not many researches on team-based learning, and the prominent use of the conventional lecture method by teachers are an indication that Nigerian mathematics education researchers and teachers have paid little attention to students' achievement in mathematics. Thus, there is the need to tackle and curb this problem in time. The goal of the study therefore, was to investigate the effectiveness of GeoGebra instruction and Team-based learning on senior secondary school students' achievement in mathematics using gender as a moderator variable. Therefore, the specific objectives of the study included:

- (i) Investigate the relative effectiveness of two teaching methods (GeoGebra instruction, team-based learning, and conventional lecture method) on students' achievement in mathematics
- (ii) Determine the influence of gender (male and female) on students' achievement in mathematics

(iii) Elucidate the interaction effect of treatment and gender on students' achievement in mathematics.

This study addressed the following research questions:

- (i) What is the main effect of treatment (GeoGebra instruction, team-based learning, and conventional lecture method) on students' achievement in Mathematics?
- (ii) How does gender influence achievement in mathematics?
- (iii) What is the extent of interaction effect of treatment and gender on students' achievement in mathematics?

The following null hypotheses were tested at 5% level of significance:

- (i) There is no significant main effect of treatment on students' achievement in mathematics.
- (ii) There is no significant main influence of gender on students' achievement in mathematics.
- (iii) There is no significant interaction effect of treatment and gender on students' achievement in mathematics.

2. METHODS

The study adopted Wquantitative research within the blueprint of pre-test, post-test non-equivalent control group quasi-experimental design to contrast the treatments' scores (at three levels) crossed with gender (at two levels) using a 3×2 factorial matrix. The quasi-experimental design was adopted because it was not possible to randomly assign individual subjects to treatment during school hours. The quasi-experimental design for this study is symbolically presented in below:

$$O_1 \rightarrow X_1 \rightarrow O_2$$

$$O_3 \rightarrow X_2 \rightarrow O_4$$

$$O_5 \rightarrow C \rightarrow O_6$$

sWhere O_1 , O_3 , and O_5 represented observations from the pretest, while O_2 , O_4 , O_6 represented observations from the post-test and X_1 , X_2 and C represented GeoGebra instruction, team-based learning and conventional lecture method respectively.

$$X_{1\text{gain}} = O_2 - O_1 \quad X_{2\text{gain}} = O_4 - O_3 \quad C_{\text{gain}} = O_6 - O_5$$

The mean gain scores between O_1 and O_2 , O_3 and O_4 and O_5 and O_6 were tested for statistical significance using the Analysis of Covariance (ANCOVA).

The target population consisted of all public senior secondary school year two students in Somolu Local Government Area of Lagos state, Nigeria. There are 25 senior secondary schools in Somolu Local Government Area. Using a simple random sampling technique, three senior secondary schools were selected from the 25 schools. One intact class each was selected from each of the three schools chosen for the study. The three intact classes were assigned to the two experimental groups and one control group through a simple random sampling technique. Altogether, the three intact classes had a sample of 183 senior secondary school year two students. In the conventional lecture method group there were 65 students. The GeoGebra instruction had 60 students while the team-based learning had 58 students. The ages of the participants ranged from 13 to 18 years with a mean_{age}=16.5 years and SD=2.4 years.

Two categories of research instruments were created in the study namely: stimulus instruments and evaluative instrument. The stimulus instruments included: Teacher's Instructional in GeoGebra instruction (TIGGI, Scott Pi=0.86), Teacher's Instructional Guide in Team-based learning (TIGTBL, Scott Pi=0.84), and Teacher's Instructional Guide in Conventional lecture method (TIGCLM, Scott Pi=0.88). The Scott Pi values were high and considered adequate for measuring inter-rater reliability in the study since they showed strong consistency among raters of the stimulus instruments. The evaluative instrument for the study consisted of only the Mathematics Achievement Test (MAT). The MAT contained 30 multiple choice questions culled from past West African Senior School Certificate Examinations (WASSCE) in mathematics with a particular focus on geometry. Geometry was chosen because of its amenability to GeoGebra instruction and students' poor performance in it as elucidated by West African Examinations Council (WAEC) Chief examiners' reports (2022) in mathematics. A Table of Specification was developed for the MAT considering the higher-order cognitive domain of Analysis, Synthesis, and Evaluation. The table of specification helped in further assessing the face and content validity of the test items. Apart from the fact that the items of the MAT were standardised, the present study conducted item analysis on the MAT. The difficulty index and discrimination power were calculated. The difficulty indices of the items on MAT ranged from 0.3 to 0.8 while the discrimination indices ranged from 0.4 to 0.8. The average difficulty index was 0.49. Kuder-Richardson 20 (KR-20) was used to determine the internal consistency reliability of the items of the MAT since each item was scored as either zero or one. A reliability coefficient of 0.89 was computed and this was considered good and adequate for the study.

The instructional guide that pertained to each intact class was used in teaching their respective students. The treatment conditions lasted for four weeks. Pretest was administered in the first week to three intact classes by their respective mathematics teachers as well as the training of the respective intact class mathematics teacher on their respective teaching strategy. Only teachers in experimental groups I and II were trained in the art and science of GeoGebra instruction and team-based learning respectively. Mathematics teacher in the control group of conventional lecture method did not receive any training. The instructional guides were used by the mathematics teachers to ensure fidelity of instruction. The second and third weeks were used for the treatment while the fourth week was used for the administration of post-test in all the three intact classes by their respective mathematics teacher. The pretest items were re-organised to form the post-test in order to eliminate the halo effect which could arise from over familiarization with the pretest.

Data collected were analyzed using descriptive statistics of mean and standard deviation to answer research questions while the hypotheses were tested using inferential statistics of Analysis of Covariance (ANCOVA). Specifically, the ANCOVA and Bonferroni's Post Hoc measure were used to further determine the direction of significance while the pretest scores were used as covariates. SPSS version 25 was used as the software for the analysis.

3. RESULTS AND DISCUSSION

3.1. Research Question One: What is the Main Effect of Treatment on Students' Achievement in Mathematics?

Table 1 indicated that students in the experimental groups (GeoGebra Instruction and Team-Based Learning) had higher post-test mean scores (20.78; 18.71 respectively) and higher mean difference (14.72; 12.86) than students in the control group (CLM) with post-test mean scores of 13.60 and mean difference of 7.63. Specifically, the treatments GGI resulted

in 244.9% increase in achievement while TBL yielded 214.8% increase on students' achievement in mathematics. The CLM yielded 127.8% increase in students' achievement.

Table 1. Descriptive statistics of achievement gain by treatment.

| Treatment | N | Pre-Test | | Post-Test | | Mean Difference (MD) | (%MD) |
|-----------|----|----------|----------------|-----------|----------------|----------------------|---------|
| | | Mean | Std. Deviation | Mean | Std. Deviation | | |
| CLM | 65 | 5.97 | 1.25 | 13.60 | 4.93 | 7.63 | (127.8) |
| GGI | 60 | 6.07 | 1.30 | 20.78 | 2.81 | 14.72 | (244.9) |
| TBL | 58 | 5.84 | 1.20 | 18.71 | 3.17 | 12.86 | (214.8) |

3.2. Research Question Two: How does Gender Influence Achievement in Mathematics?

Table 2 showed the descriptive statistics of mathematics achievement by gender classification. **Table 2** indicated that male students progressed from a mean achievement score of 5.99 to 17.41 (mean difference =11.42) while the females progressed from a mean achievement score of 5.93 to 17.71 (mean difference=11.80). The mean difference in achievement in mathematics of females was slightly higher than that of the males.

Table 2. Descriptive statistics of mathematics achievement gain by gender.

| Treatment | N | Pre-Test | | Post-Test | | Mean Difference (MD) | (%MD) |
|-----------|----|----------|----------------|-----------|----------------|----------------------|---------|
| | | Mean | Std. Deviation | Mean | Std. Deviation | | |
| Male | 91 | 5.99 | 1.29 | 17.41 | 5.06 | 11.42 | (190.7) |
| Female | 92 | 5.93 | 1.21 | 17.74 | 4.69 | 11.80 | (198.9) |

3.3. Research Question Three: What is The Extent of Interaction Effect of Treatment and Gender on Students' Achievement in Mathematics?

The descriptive statistics relating to the interaction of treatment and gender on students' achievement in mathematics is shown in **Table 3**. The analysis revealed that within the GeoGebra instruction group, male students progressed from a mean achievement score of 6.11 to 20.81 (mean difference = 14.70) representing 240.6% increase in achievement while female students in that experimental group advanced from a mean achievement score of 6.03 to 20.76 (mean difference = 14.73) representing 244.3% increase in achievement. In the TBL experimental group, male students progressed from a mean achievement score of 5.90 to 18.83 (mean difference = 12.93) representing 219.2% increase in achievement, while the females progressed from a mean achievement score of 5.79 to 18.57 (mean difference=12.79) representing 220.9% increase in achievement. In the CLM control group, male students progressed from a mean achievement score of 5.97 to 13.44 (mean difference = 7.4) representing 129.4% increase in achievement, while the females progressed from a mean achievement score of 5.97 to 13.77 (mean difference= 7.81) representing 130.8% increase in achievement. Clearly, the effect of interaction between treatment and gender was highest on the mathematics achievement in the GeoGebra instruction female, then male students, followed by the TBL male then female students. Lastly, the effect of treatment and gender interaction was least for the CLM group female, then male.

Table 3. Descriptive statistics of mathematics achievement gain by interaction of treatment.

| Treatment | Gender | N | Pre-Test | | Post-Test | | Mean Difference (MD) | (%MD) |
|-----------|--------|----|----------|----------------|-----------|----------------|----------------------|---------|
| | | | Mean | Std. Deviation | Mean | Std. Deviation | | |
| CLM | Male | 34 | 5.71 | 1.29 | 13.44 | 5.29 | 7.47 | (129.4) |
| | Female | 31 | 5.97 | 1.22 | 13.77 | 4.57 | 7.81 | (130.8) |
| GGI | Male | 27 | 6.11 | 1.31 | 20.81 | 2.57 | 14.70 | (240.6) |
| | Female | 33 | 6.03 | 1.31 | 20.76 | 3.02 | 14.73 | (244.3) |
| TBL | Male | 28 | 5.90 | 1.30 | 18.83 | 3.21 | 12.93 | (219.2) |
| | Female | 30 | 5.79 | 1.01 | 18.57 | 3.19 | 12.79 | (220.9) |

3.4. H₀1: There is No Significant Main Effect of Treatment on Students' Achievement in Mathematics

The results in **Table 4** showed that there was a significant main effect of treatment on students' achievement in mathematics after controlling for the effect of pre-test scores ($F(2,182)=84.193$, $P=0.000$, $\eta_p^2=0.489$). Since $p < 0.05$, it follows that the main effect of treatment on students' achievement in mathematics was statistically significant.

Table 4. Summary of analysis of covariance of achievement in mathematics scores by treatment and gender.

| Source | Type III Sum of Squares | Df | Mean Square | F | Sig. | Partial Eta Squared |
|-------------------|-------------------------|-----|-------------|--------|------|---------------------|
| Corrected Model | 2562.181 ^a | 6 | 427.030 | 42.982 | .000 | .594 |
| Intercept | 413.860 | 1 | 413.860 | 41.657 | .000 | .191 |
| Covariate | 840.387 | 1 | 840.387 | 84.588 | .000 | .325 |
| Treatment | 1672.920 | 2 | 836.460 | 84.193 | .000 | .489 |
| Gender | .640 | 1 | .640 | .064 | .800 | .000 |
| Treatment *Gender | 1.280 | 2 | .640 | .064 | .938 | .001 |
| Error | 1748.573 | 176 | 9.935 | | | |
| Total | 60828.000 | 183 | | | | |
| Corrected total | 4310.754 | 182 | | | | |

a. R Squared = .594 (Adjusted R Squared = .581)

b. Computed using alpha = 0.05 *significant at $p < 0.05$

The result of the post hoc analysis **Table 5** indicated that the mean post-test scores of students in one group were significantly higher than the other, with the GeoGebra Instruction group as the highest, followed by Team-Based Learning and lastly Conventional Lecture Method. The mean difference between GeoGebra Instruction and Team-Based Learning experimental groups was quantified as 1.69; $p < 0.05$ which was statistically significant. The mean difference between GGI and CLM was derived as 7.003, which was also statistically significant. Lastly, the mean difference between the TBL and CLM was derived as 5.313, $p < 0.05$ which was also statistically significant. The result revealed the fact that the experimental methods (GGI & TBL) were significantly better than the control group (CLM). The direction of decreasing effects of instructional strategy on achievement in mathematics was $CLM < TBL < GGI$.

Table 5. Pairwise comparisons of mathematics achievement (Post Hoc).

| (I) Treatment | (J) Treatment | Mean difference | Std. error | Sig. ^b | 95% confidence interval for mean difference ^b | |
|---------------|---------------|---------------------|------------|-------------------|--|-------------|
| | | | | | Lower bound | Upper bound |
| CLM | GGI | -7.003 [*] | .566 | .000 | -8.372 | -5.634 |
| | TBL | -5.313 [*] | .570 | .000 | -6.692 | -3.935 |
| GGI | CLM | 7.003 [*] | .566 | .000 | 5.634 | 8.372 |
| | TBL | 1.690 [*] | .584 | .013 | .279 | 3.100 |
| TBL | CLM | 5.313 [*] | .570 | .000 | 3.935 | 6.692 |
| | GGI | -1.690 [*] | .584 | .013 | -3.100 | -.279 |

a. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

3.5. H₀2: There is No Significant Main Influence of Gender on Students' Achievement in Mathematics

Analysis of Covariance **Table 4** revealed that after controlling for the effect of pre-test scores of students, there was no significant effect of gender on students' achievement in mathematics $F(1,182)=0.064$, $P=0.800$, $\eta_p^2=0.000$). Clearly, $p>0.05$, hence we did not reject the null hypothesis and concluded based on the data collected that no gender disparity existed in mathematics achievement of students. In fact, gender did not account for the difference observed in the scores, as partial eta squared put the contribution of gender to the variation in achievement scores at 0%, implying that variation observed was due to factors other than gender.

3.6. H₀3: There is No Significant Interaction Effect of Treatment and Gender on Students' Achievement in Mathematics

The interaction effect of treatment and gender on students' post-test achievement according to statistics in **Table 4** ($F_{(2,182)}=0.064$, $P=0.938$, $\eta_p^2 = 0.001$) was not statistically significant, although the interaction accounted for 0.1% of the variation in the students' scores in achievement in mathematics. Thus, it was concluded that the interaction effect of treatment and gender was not significant and the null hypothesis was not rejected.

The summary of ANCOVA analysis on the main effect of treatment on the achievement of students in mathematics showed that 48.9% of the variation in students' mathematics achievement can be attributed to the treatment. This showed that students' mathematics achievement was significantly enhanced after they were exposed to the GGI and TBL treatment as against the conventional lecture method (CLM).

Analysis also revealed that students exposed to GGI treatment had a higher achievement mean score than students exposed to TBL treatment which could be due to the fact that students were able to explore, interact and visualize mathematical concepts in the GGI group. The finding is in agreement with the results of some researchers (Aliyu, 2019; Isah, 2015; Burgess, 2019) who all found out that students taught with GGI and TBL achieved significantly higher than those taught with CLM. However the present study result was in disagreement with findings of some other researchers (Masri et al., 2016; Killian & Bastis, 2015) who found no significant difference in the mean performance of students based on treatment. The effectiveness of GGI and TBL in this study conformed to the power of constructivist learner-centred teaching strategies in ensuring procedural and conceptual understanding of

mathematics for all students. The CLM had been criticised for a decline in students' achievement in mathematics due to great emphasis on teachers' activities at the expense of students' conceptual understanding of mathematics (Awofala & Agbolade, 2024; Awofala & Lawani, 2020a; Awofala & Lawani, 2020b).

Female students were observed to have a slightly higher achievement mean score than male students, however, the effect of gender on students' achievement was not statistically significant, and this could be a pointer to the strength of treatment to eliminate gender differences in mathematics achievement. The result of the analysis as shown in Table 4 indicates that the influence of gender on students' achievement in mathematics is not significant, which is in agreement with the studies of some researchers (Fatade *et al.*, 2012; Chinelo, 2020; Awofala & Anyikwa, 2014; Awofala, 2017; Alordiah *et al.*, 2015). The statistically non-significant gender difference disagrees with the findings of other researchers (Awofala, 2011; Abari *et al.*, 2019; Ajai & Imoko, 2015) who found significant gender differences in students' achievement in mathematics. Thus, sex stereotyping in mathematics education (Awofala, 2011, 2008) in Nigeria may be waning. This shows that the cultural, social and psychological factors were the same for male and female students in this study and that there was no innate differences in ability in mathematics.

No significant interaction effect of treatment and gender was found on students' achievement in mathematics. This means that the effect of treatment was similar across gender, and suggests no differential experiences of males and females within and outside the classroom. The findings of this present study was corroborated by researchers (Eze, Ezenwafor, & Obidile, 2016; Ajai *et al.*, 2014) whose studies established no statistically significant gender difference in academic achievement of students when exposed to treatments. However, some studies had found significant interaction effect of treatment and gender on students' achievement in mathematics (Akinsola & Awofala, 2009; Awofala & Nwajuwa, 2023; Ani *et al.*, 2021) thereby disagreed with the present study result. This could be as result of the difference in the level of students involved in the study. The non-significant interaction effect of treatment and gender on students' achievement in mathematics recorded in this study showed that male and female students did not respond differently to the content being presented, instructional strategy being adopted as well as the learning environment.

4. CONCLUSION

Students' achievement in mathematics which was found to be low in previous studies was improved as the use of teaching methods which are student-centred were incorporated. In other words, methods which are interactive and fun can help improve students' achievement in mathematics. Treatment accounted for 48.9% of the variation observed in students' achievement in mathematics. The present study showed that there was no significant main effect of gender on students' achievement in mathematics. Thus, gender was not a factor in students' achievement in mathematics. Lastly, there was no significant interaction effect of treatment and gender on students' achievement in mathematics. This meant that treatment was not gender sensitive. The following recommendations were made based on the findings of the study.

- (i) Teachers should embrace GGI and TBL in the teaching of mathematics.
- (ii) Educational administrators should provide opportunities for in-service training for mathematics teachers in order to equip them with competencies needed in the use of GGI and TBL for teaching.

- (iii) Teachers should encourage peer-teaching among the students by engaging them to form heterogeneous groups for study purpose.
- (iv) Curriculum planners should incorporate GGI and TBL as a strategy for teaching mathematics in secondary education level.
- (v) Equal opportunity and the same level of encouragement should be given to students irrespective of their gender.
- (vi) Government should provide required ICT facilities in order to make GeoGebra popular among teachers and students.

5. ACKNOWLEDGMENT

Many thanks to the mathematics teachers and students that participated in the study.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

7. REFERENCES

- Adeniyi, C. O. and Awofala, A. O. A. (2023). Effect of just-in-time teaching strategy on post basic-school pupils' achievement in mathematics in Lagos State. *Journal of Curriculum and Instruction*, 14(1), 203-212.
- Ajai, J. T, Imoko, B. I., and O'kwu, E. I. (2014). Comparison of the learning effectiveness of problem-based learning (PBL) and conventional method of teaching algebra. *Journal of Education and Practice*, 6(2), 84-104.
- Ajai, J. T. and Imoko, B. I. (2015). Gender differences in mathematics achievement and retention scores: A case of problem-based learning method. *International Journal of Research in Education and Science*, 1(1), 45- 50.
- Akinsola, M. K. and Awofala, A. O. A. (2009). Effects of personalization of instruction on students' achievement and self-efficacy in mathematics word problems. *International Journal of Mathematical Education in Science and Technology*, 40(3), 389 – 404.
- Aliyu, J. (2019). Effect of geoGebra and paper/pencil to the teaching and learning of simultaneous linear equation in some selected junior secondary schools at Zaria, Kaduna state of Nigeria. *The Journal of Mathematical Association of Nigeria*, 44(1), 158-165.
- Alordiah, C. O., Akpadaka, G., and Oviogboda, C. O. (2015). The influence of gender, school location and socio-economic status on students' academic achievement in mathematics. *Journal of Education and Practice*, 16(17), 130-136.
- Ani, M. I., Obodo, A. C., Ikwueze, C. C., Festus, T. T. (2021). Effect of gender in basic science students' academic achievement in secondary schools in Enugu education zone, Enugu state, Nigeria. *Unizik Journal of Research and Policy Studies*, 2(1), 9-14.
- Arigbabu, A. A. and Mji, A. (2004). Is gender a factor on mathematics performance among Nigerian preservice teachers? *Sex Roles: A Journal of Research*, 51(2), 749-753.

- Awofala, A. O. A, Fatade, A. O., and Ola-Oluwa, S. A. (2012). Achievement in cooperative and individualistic goal-structured junior secondary school mathematics classrooms in Nigeria *International Journal of Mathematics Trends and Technology*, 3(1), 7 - 12.
- Awofala, A. O. A. (2008). Women and the learning of mathematics. *African Journal of Historical Sciences in Education*, 2(1), 195 – 213.
- Awofala, A. O. A. (2011). Is gender a factor in mathematics performance among Nigerian senior secondary students with varying school organization and location? *International Journal of Mathematics Trends and Technology*, 2(3), 17-21.
- Awofala, A. O. A. (2017). Assessing senior secondary school students' mathematical proficiency as related to gender and performance in mathematics in Nigeria. *International Journal of Research in Education and Science*, 3(2), 488-502.
- Awofala, A. O. A. and Anyikwa, B. E. (2014). Assessing adult learners' numeracy as related to gender and performance in arithmetic. *Journal of New Approaches in Educational Research*, 3(2), 83-92.
- Awofala, A. O. A. and Lawal, R. F. (2022). The relationship between critical thinking skills and quantitative reasoning among junior secondary school students in Nigeria. *Jurnal Pendidikan Matematika (Kudus)*, 5(1), 1-16.
- Awofala, A. O. A. and Lawani, A. O. (2020a). Increasing mathematics achievement of senior secondary school students through differentiated instruction. *Journal of Educational Sciences*, 4(1), 1-19.
- Awofala, A. O. A. and Lawani, A. O. (2020b). Examining the efficacy of co-operative learning strategy on undergraduate students' achievement in mathematics. *International Journal of Pedagogy and Teacher Education*, 4(1), 59-82.
- Awofala, A. O. A. and Uwajuwa, N. (2023). Computer assisted instruction and mastery learning strategy as determinants of senior secondary school students' achievement in mathematics. *Nigerian Online Journal of Educational Sciences and Technology*, 5(1), 67-79.
- Awofala, A. O. A., Akinoso, S. O., and Adebayo, A. (2022). Exploring preservice mathematics and social studies teachers' internet addiction as connected with gender and grade point average. *Pedacta*, 12(1), 1-6.
- Awofala, A. O. A., and Agbolade, F. O. O. (2024). Effect of peer-tutoring strategy on senior secondary school students' achievement in mathematics. *ASEAN Journal for Science Education*, 3(1), 1-12.
- Awofala, A. O. A., and Akinoso, S. O. (2024). Altering students' mindsets and enhancing engagement in mathematics in a problem-based learning. *ASEAN Journal of Science and Engineering Education*, 4(2), 193-210.
- Awofala, A. O. A., Arigbabu, A. A. and Awofala, A. A. (2013). Effects of framing and team assisted individualised instructional strategies on senior secondary school students' attitudes toward mathematics. *Acta Didactica Napocensia*, 6(1), 1 – 22.

- Awofala, A. O. A., Ojo, O. T., Awofala, A. A. and Olabiyi, O. S. (2020). Is gender a factor in 21st century skills in education among future science, technology and mathematics (STM) teachers in Nigeria. *Beder University Journal of Educational Sciences*, 23, 39-69.
- Berrett, D. (2012). How 'flipping' the classroom can improve the traditional lecture. *The Chronicle of Higher Education*, 12(19), 1-3.
- Bulut, M., Akcakin, H. U., Kaya, G., and Akcakin, V. (2016). The effects of GeoGebra on third grade primary students' academic achievement of fractions. *Mathematics Education*, 11(2), 327-335.
- Burgess, A., McGregor, D., and Mellis, C. (2014). Applying established guidelines to team-based learning programs in medical schools: A systematic review. *Academic Medicine*, 89, 678-88.
- Burgess, A., Haq, I., Bleasel, J., Roberts, C., Garsia, R., Randal, N., and Mellis, C. (2019). Team-based learning (TBL): A community of practice. *BMC Medical Education*, 19(1), 369.
- Chinelo, B. O. (2020). The influence of gender on mathematics achievement of secondary school students in Bayelsa state. *African Journal of Studies in Education*, 14(2), 196-206.
- Eze, T. I., Ezenwafor, J. I., and Obidile, I. J. (2016). Effects of problem-based teaching methods on students' academic performance and retention in financial accounting in technical colleges in Anambra State. *Scholars Journal of Arts, Humanities and Social Sciences*, 4(6A), 643-639.
- Fatade, A. O., Arigbabu, A. A. Mogari, D., and Awofala, A. O. A (2014). Investigating senior secondary school students' beliefs about further mathematics in a problem-based learning context. *Bulgarian Journal of Science and Education Policy*, 8(1), 1-42.
- Fatade, A. O., Nneji, L. M., Awofala, A. O. A., and Awofala, A. A. (2012). Mode of entry and gender as determinants of Nigerian pre-service teachers' performance in degree mathematics and science courses. *International Journal of Mathematics Trends and Technology*, 3(3), 103-109.
- Islahi, F. and Nasrin, A. (2019). Exploring teacher attitude towards information technology with a gender perspective. *Contemporary Educational Technology*, 10(1), 37-54.
- Kesan, C and Caliskan, S. (2013). The effect of learning geometry topics of the 7th grade in primary education with dynamic geometer's sketchpad geometry software for success and retention. *Turkish Online Journal of Educational Technology*, 12, 131-138.
- Killian, M. and Bastas, H. (2015). The effects of team-based learning on students' attitudes and students' performances in introductory sociology classes. *Journal of Scholarship of Teaching and Learning*, 15(3).
- Masri, R., Hiong, T. S., Tajudin, M., and Zamzamin, Z. Z. (2016). The effects of using GeoGebra teaching strategy in Malaysian secondary schools: A case study from Sibul, Sarawak. *Geografia - Malaysian Journal of Society and Space*, 12(7), 13-25.
- Michaelsen, L. K. and Sweet, M. (2008). The essential elements of team-based learning. *New Directions for Teaching and Learning*, 2008(116), 7-27.

- Michaelsen, L. K., and Sweet, M. (2011). Team-based learning. *New Directions for Teaching and Learning*, 128(128), 41-51.
- Olabiyi, O. S. and Awofala, A. O. A. (2019). Effect of co-operative learning strategy on senior secondary school students' achievement in woodwork technology. *Acta Didactica Napocensia*, 12(2), 171-182.
- Parmelee, D., Michaelsen, L. K., Cook, S., and Hudes, P. D. (2012). Team-based learning: A practical guide: AMEE guide no 65. *Medical Teacher*, 34, e275–e287.