Available online at: https://jurnal-fkip.ut.ac.id/index.php/ijrse/issue/archive
International Journal of Research in STEM Education (IJRSE)
ISSN 2721-2904 (online)
Volume 6 Number 2 (2024): 85 - 97

Enhancing Students' Achievement in Geometry using Laboratory-Based Instructional Method

[1]Ajai, John Tyavbee, [2]Ogungbile, Titilayo and [3]Nguuma Jimin
[1,2] Department of Science Education, Taraba State University, Jalingo
[3] Department of Science Education, Sule Lamido University, Kafi-Hausa, Jigawa
[1]ajai.j@tsuniversity.edu.ng

Abstract

This study investigated the effect of laboratory-based instructional methods on students' achievement in geometry within the educational context of Jalingo Metropolis, Taraba State, Nigeria. Recognising the potential of hands-on, experiential learning approaches in mathematics education, particularly in geometry, this research explored the effectiveness of laboratory-based instruction in enhancing student performance. Guided by three research questions and hypotheses, the quasi-experimental research design was employed on a sample of 160 Upper Basic II students, through pre-and post-test assessments. The Geometry Achievement Test (GAT) with a reliability index of 0.91 for the GAT, determined using the K-R20 method, was used for data collection. The mean and standard deviation statistics were employed to answer the three research questions, while covariance (ANCOVA) analysis was employed to test all hypotheses at a significance level of 0.05. The study found a significant improvement in geometry achievement among students exposed to the laboratory-based method, with 56% of the achievement score variance attributed to this method. Additionally, it identifies a noteworthy difference in achievement scores between male and female students taught geometry using the laboratory-based approach, with a significant interaction effect observed between the teaching method and gender. These findings emphasise the potential of incorporating laboratory-based instructional methods in mathematics education to enhance student achievement and promote a deeper understanding of geometric concepts. Overall, the study contributes valuable insights to the discourse on innovative pedagogical practices in mathematics instruction, offering guidance for educators and policymakers aiming to improve mathematics education in similar contexts.

Keywords: *Laboratory method, geometry, achievement of student, gender*

INTRODUCTION

The traditional lecture method has been the mainstay in mathematics teaching for many years. Based on direct instruction, this approach has the teacher directing students through mathematical ideas, problem-solving strategies, and theory application in an organised manner. It was recognised more than thirty years ago that the traditional method would not always be the best way to help students learn and apply what they had learned (Lugosi & Uribe, 2020). Chickering and Gamson (1991) presented an argument that learning is different from passively watching something occur, which makes their argument for why a lecture-based method is not the best one for teaching. Students learn little when they merely sit in class and pay attention to their teachers.

Corresponding author:
Isaac Bamikole Ogunsakin, sakinbamikole@yahoo.com,
DOI: https://doi.org/10.33830/ijrse.v6i2.1706

It is crucial to note that the President's Council of Advisors on Science and Technology (2012) emphasises that classroom methods involving active learning enhance the retention of information and critical thinking skills. Stanberry (2018) believes that dedicating more time in class to student participation is beneficial for better learning results. According to Lugosi and Uribe (2020), most studies conducted on this topic agree that increasing student participation is crucial. This contrasts with a sole dependence on lecturing, and such methods also contribute to increased persistence among students pursuing STEM majors. To make sure that students achieve the required learning aims, various kinds of classroom methods of instruction and the right instructional resources must be used (Azid et al., 2020).

One of the subjects that must be taught by doing, not by reading and reciting, is mathematics; otherwise, it creates issues for both teaching and learning. The use of the right tools and resources is needed for learning mathematics. According to Hwa (2018), the only way to make mathematics instruction and learning realistic, fascinating, and engaging is to use methods of instruction and engaging activities that students enjoy. When students receive new mathematical information in a way that makes sense in their frame of reference (that is, in their inner worlds of memory, experience, and response), they learn new mathematical knowledge (Rach & Ufer, 2020).

Pedagogical research is constantly searching for inventive methods to teach mathematics, as the area is consistently expanding. Agwagah (1997) argued that the issue of ineffective instruction can be resolved by a purposeful and planned deployment of the mathematics laboratory. The idea of mathematics laboratories in mathematics instruction had previously been suggested by Srinivasa (1978). This, in Srinivasa's opinion, will help students form concepts through their interactions with different objects. In this instance, the unclear ideas and made-up objects take on real form, and students perform better at comprehending. According to Okigbo and Osuafor (2008), learning becomes dull and unattended when it is done through verbal recitals and drills. Considering this context, this study investigated how instructional methods based on laboratory activities affect student's achievement in geometry in the Jalingo metropolis, Taraba State, Nigeria.

Research Objectives:

In response to the evolving demands of educational methods that promote active learning and engagement, particularly in the field of mathematics, this study aims to explore alternative instructional strategies. It is imperative to examine more interactive and student-centered approaches that might replace or supplement traditional lecture methods, which have been criticized for their limited effectiveness in facilitating deep understanding and retention of complex subjects like geometry. Given this background, the following research objective has been formulated:

1. To what extent does the laboratory-based method affect Upper Basic II students' achievement in geometry?
2. What is the difference between the Upper Basic II male and female students' achievement in geometry when the laboratory-based method is used?
3. What is the interaction effect of the method of teaching and gender on Upper Basic II students' achievement in geometry?

Literature Review

In Ezeliora's (2001) perspective, a science laboratory is identified as a workspace where scientific activities are conducted or where science is practised within a conducive environment. Omiko (2007) further characterises a laboratory as a designated space, be it a room or building, or a specific time limit, furnished and allocated for practical or experimental studies. Omiko emphasises the laboratory's significance as the core of a robust scientific programme, enabling students in the school to gain experiences aligned with the objectives of scientific literacy. This underscores the essential role of a well-equipped laboratory in secondary schools, as posited by Omiko, where practical activities are essential for imparting science process skills to learners and ensuring effective science teaching and learning. Hence, the laboratory-based teaching method encompasses instructional strategies focusing on students' hands-on experiences through experimentation, fieldwork, and activity projects.

The laboratory-based instruction, according to Joshi (2008), is a special teaching method and a crucial component of successful science education. With this method, teacher dominance is reduced, while students are encouraged to conduct experiments to extract scientific rules and concepts. Richard (2009) quoted Landauer, highlighting that the implementation of the laboratory-based strategy closely resembles the hybrid approach. This hybrid approach amalgamates various methods related to students' conceptual adoption, incorporating expository learning, cooperative inquiry, solution workshops, and virtual workshops utilising computer-internet interfaces. The strategy encompasses discussions about computer technology within the context of laboratory-based learning strategies. Students interact directly with their peers and teachers in a well-designed laboratory, allowing for effective monitoring, assessment, and enhancement of learning (Ojediran et al., 2014). Ngala (2019) observed that the varied activities within a laboratory-based instructional method collectively contribute to practical exercises, fostering engagement within and beyond the classroom. These activities may involve individuals, small groups, or the entire class, providing a dynamic and interactive learning experience. Laboratory-based strategy, according to Dafid et al. (2022), is a learning strategy that allows students to empirically practice cognitive, affective, and psychomotor abilities using laboratory facilities.

Some academics commonly designate this approach simply as practical. According to Tambo (2012), laboratory-based teaching is distinctly characterised as an interactive learning process where, under the guidance of an instructor, students explore various facets of a subject. Tambo emphasises that the central aim of this methodology is to address specific challenges or provide answers within the educational sphere. Echoing this sentiment, Nekang (2016) describes the laboratory-based instructional method as a pedagogical tool guiding students through practical experiments, thereby cultivating skills in observation, tactile exploration, approximation, and estimation. Fundamentally, the laboratory-based instructional method functions as a conduit for imparting learners with both generic and scientific process skills, equipping them to tackle real-world problems. This empowerment stems from the active involvement of learners in constructing knowledge during the teaching-learning process.

Relatedly, Dienye and Gbamanja (1990) observe that the laboratory-based teaching method adopts a dual approach, incorporating both exercise and experimental methods. This dual-pronged strategy, facilitated by one or more instructors, proves invaluable in the realm of science education. The experimental approach encourages students to seek information through hands-on experimentation, necessitating careful observation and data interpretation. These processes embody qualities of inquiry, investigation, and grappling with the unfamiliar, catering to diverse learning preferences and fostering a holistic educational experience.

For centuries, laboratory-based instructional methods have been the benchmark for training practical skills. To put theoretical knowledge into practical situations, laboratory-based instructional methods are needed. However, most secondary school laboratories are assigned to physics, chemistry, and biology, each with specialised technicians. It is rare for mathematics students in Nigeria to use the scientific laboratory because mathematics is not considered a practical science. According to Hernández-de-Menéndez et al. (2019), even teachers do not understand the need for a laboratory to teach mathematics. This misconception notwithstanding, the use of laboratory-based instruction in mathematics lessons cannot be underestimated. Students acquire an in-depth understanding of mathematical topics. They are better prepared for success in both academic and real-world situations when laboratory-based methods of instruction are incorporated into mathematics learning. This approach to learning is comprehensive and effective (OpenAI, ChatGPT (3.5), 2024). Ngala (2019), citing Udondu (2009) and Omiko (2015) emphasises the advantages of employing the laboratory-based teaching approach, which encompasses improving comprehension of science and technology, nurturing problem-solving abilities, promoting the emulation of scientists, and cultivating enthusiasm, attitudes, and values towards science.

There is a plethora of research on the benefits of laboratory-based education. Ngala's (2019) research findings indicate that employing laboratory-based teaching approaches improves the development of fundamental science process skills among high school students studying biology. Ngala advised that instructors in secondary education institutions utilize this method, particularly when covering topics that necessitate hands-on activities, to enhance students' acquisition of science skills in biology effectively. Similar findings were made by Anakpua et al. (2020), who showed that integrating mathematics laboratories into the teaching of mathematics promotes student-centred learning and improves problem-solving abilities. One of their suggestions is that teachers of mathematics use a variety of teaching strategies and educational materials to help students overcome the abstract character of the subject and improve their performance. In their study conducted in 2020, Rathod and Amini found that an instructional approach focused on a mathematics laboratory proved effective in aiding eighth-grade students' understanding of the concepts taught within the quadrilateral's unit of mathematics.

According to Dafid et al. (2022), learning linear geometry in a laboratory setting is a more effective approach. Bindu and Ramakrishna's research, conducted in 2023, revealed that the conventional method of teaching and learning mathematics content delivery for eighth-grade students was comparatively less successful in fostering the development of mathematical concepts compared to the laboratory-based approach. The laboratory method fosters scientific thinking in students and not only gets their attention but also improves their performance and engagement (Jepkosgei, 2023). It also helps students acquire the abilities they need for further study and research. According to the study, teachers should incorporate the laboratory technique into their lesson plans to guarantee that students are more engaged and involved in mathematical activities. It also emphasises how important it is for teachers to be trained in properly applying the laboratory technique.

The theoretical anchor for laboratory-based methods in teaching mathematics often draws upon the principles of constructivism and hands-on learning. Elliott et al. (2000) defined constructivism as an approach to learning that asserts individuals actively construct their knowledge, and reality is shaped by the experiences of the learner. According to McLeod (2024), constructivism is a learning theory that emphasises how learners actively shape their cognition. Learners gather and process information, create mental models, apply new information to preexisting frameworks, and actively reflect on their experiences. Expanding on constructivist concepts, Arends (1998) suggests that constructivism advocates for learners to personally construct meaning through experiences, where meaning is shaped by the interplay between prior knowledge and new encounters.

In the context of mathematics education, laboratory-based methods provide students with opportunities to engage directly with mathematical concepts through experimentation, exploration, and discovery. These methods emphasise active participation, inquiry, and problem-solving, allowing students to build their understanding of mathematical concepts through first-hand experiences. The impetus for this study was provided by the aforementioned, which prompted an investigation into the effect of laboratory-based teaching method on geometry achievement among secondary school students in the Jalingo metropolis of Taraba State, Nigeria.

RESEARCH METHOD

This study adopted a quasi-experimental design, employing a non-equivalent pre-and post-test design. The rationale is given the impracticality of total randomization due to the use of intact classes. Because intact classes were used, it was difficult to ensure group equivalency; therefore, pre-test results had to be used to determine group equivalency. The sample was divided into two groups: Group A served as the experimental group, using the laboratory-based method, while Group B acted as the control group, adhering to the conventional approach. Initial assessment through pre-testing established the baseline for both groups. Following six weeks of instruction on specific geometrical concepts, a post-test was administered to assess achievement, serving as the dependent variable. The post-test data were used to calculate the gain scores following treatment.

The study population comprised 6,698 students, encompassing all students in Upper Basic II within the Jalingo metropolis of Taraba State, Nigeria. This population consisted of Upper Basic II students from 25 schools in the Jalingo metropolis. Among these students, there were 3,612 males and 3,086 females. The Upper Basic II students were used simply because this class appears to be more stable, unlike Upper Basic I, which is newly admitted, and Upper Basic III, which is in the final year of the Upper Basic School. The sample comprised 160 Upper Basic II students from two schools in Jalingo, Taraba State. The schools were selected purposefully based on the criteria of mathematics teachers holding a bachelor's degree in mathematics education, (i.e. B. Sc. (Ed.) Mathematics) and possessing at least three years of teaching experience. Subsequently, the schools were randomly assigned to either the experimental or control group.

The study utilised participants within intact classes and implemented a specially designed methodology instructional package (MIP) for instruction. The study was guided by the three hypotheses, which were tested at a 0.05 level of significance.

1. H01: The laboratory-based method has no significant effect on Upper Basic II students' achievement in geometry.
2. H02: There is no significant difference between Upper Basic II male and female students' achievement in geometry when the laboratory-based method is used.
3. H03: There is no significant interaction effect of the method of teaching and gender on Upper Basic II students' achievement in geometry.

The MIP comprises lesson plans that utilize identical curriculum materials but employ different instructional methods. In the control group, class activities were conducted in a traditional classroom setting. Conversely, the experimental group engaged in learning within a laboratory environment provided by the MIP, where students participated in practical exercises such as experiments and laboratory work within the mathematics classroom. The instructional period consisted of ten 40-minute lessons aimed at teaching concepts related to geometric concepts.

Data on achievement were collected using the Geometry Achievement Test (GAT), consisting of fifty multiple-choice items with four options each. Three experts specializing in mathematics education, science education, and educational evaluation and measurement evaluated the GAT to ascertain its face, content, and construct validity. Subsequent item analysis revealed a reliability index of 0.91 for the GAT, determined using the K-R20 method.

The data collected through GAT were categorized into pre-test and post-test measurements for both the experimental and control groups. Additionally, the data were further classified by gender, as gender was considered a moderator variable in the study. While the mean and standard deviations were employed to answer the research questions, covariance (ANCOVA) analysis was employed to test all hypotheses at a significance level of 0.05. Because intact classes were used, ANCOVA was used to correct for the initial (baseline) disparities between the groups and ensure that the groups were equivalent across factors that could differ. Additionally, ANCOVA examines significant mean differences while simultaneously controlling for the effects of one or more covariates.

RESULTS AND DISCUSSION

Results

Research question one: *To wjhat extent does the laboratory-based method affect Upper Basic II students' achievement in geometry?*

Table 1 . Mean Achievement Scores of Students in the laboratory-based method compared to the conventional lecture method.

Group		N	Pretest	Post-test		Mean		
			mean	std. dev	mean	std. dev	gain	
L-B Grp	93	9.19	3.68		24.15	4.87		14.96
Control Grp	67	8.61	2.63		14.63	3.28		6.02
Mean difference		0.58			9.52			8.94

L-B = Laboratory-based method**; Control Grp =** conventional lecture method

Table 1 shows that the experimental group taught geometry using the laboratory-based method had a pretest mean score of 9.19 with a standard deviation of 3.68, while the control group taught using the conventional lecture method had a pretest mean score of 8.61 with a standard deviation of 2.63. The difference between the pretest scores of the experimental group and the control group is 0.58. After the effect of the pretest has been statistically removed, the posttest mean score of the students taught using the laboratory-based method stands at 24.15, while that of their counterparts taught using the conventional lecture method is 14.63. The standard deviation scores of the two groups indicate that the data sets in the two groups exhibit a reasonable degree of consistency. The difference between the post-test mean score of the students in the two groups is 9.52 and in favour of the group taught geometry using a laboratory-based method.

The mean gain (that is, the difference between the pretest and posttest scores) of students taught using the laboratory-based method is 14.96, while that of those taught using the conventional instruction method is 6.02. The mean gain shows that the laboratory-based group gained higher than the control group by 8.94 units. Therefore, it can be inferred that the laboratory-based method was highly effective in enhancing students' performance in geometry.

Research question two: *What is the difference between the Upper Basic II male and female students' achievement in geometry when the laboratory-based method is used?*

Table 2. **Mean Achievement Scores of male and female students in the laboratory-based method**

Gender	N	Pretest		Post-test		Mean gain
		mean	std. dev	mean	std. dev	
Male	42	8.98	4.23	25.31	5.13	16.33
Female	51	9.37	3.19	23.19	4.47	13.82
Mean difference		0.39		2.12		2.51

Table 2 shows that male students had a pretest achievement mean score of 8.98 with a standard deviation of 4.23, while female students had a pretest mean score of 9.37 with a standard deviation of 3.19.

The difference between the pretest achievement scores of the experimental group and the control group is 0.39. After the effect of the pretest has been statistically removed, the posttest mean score of male students stands at 25.31, while that of their female counterparts is 23.19. The standard deviation scores of the male and female students indicate that the data sets in the two groups exhibit a reasonable degree of consistency. The difference between the achievement posttest mean score of the male and female students is 2.12 and in favour of the male students.

In the same vein, the male students gained 16.33 in achievement scores, while the female students gained 13.82. This implies that, on average, male students experienced a greater increase in achievement scores compared to female students. Specifically, the difference in the mean gain between the two groups indicates that male students, on average, improved their achievement scores by 2.51 more units than their female counterparts throughout the study. This suggests a disparity in the rate of achievement between male and female students, with males exhibiting a larger improvement in achievement scores when taught geometry using a laboratory instruction strategy.

Research Question Three: *what is the interaction effect of the method of teaching and gender on students' achievement in geometry?*

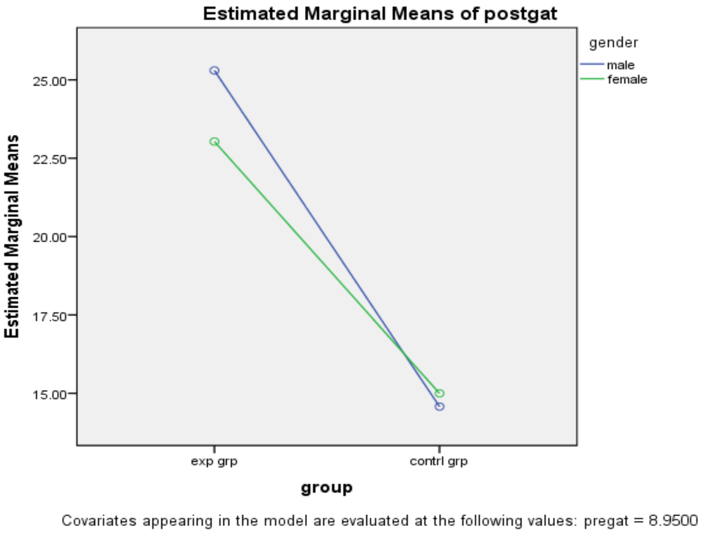

Figure 1. Profile plot of interaction for the method of teaching and gender

Figure 1 is a profile plot of the adjusted means for the achievement test, split for male and female students and method of teaching (laboratory-based method and conventional lecture method). The plot shows that the male and female students' achievement scores intersect, which is indicative of an interactive effect. The lowest achievement scores of the males and females in geometry occur in the conventional lecture method. On the other hand, the highest score was recorded for male students in the laboratory-based method. This suggests that males and females appear to respond differently to the method of teaching and that in designing the laboratory-based method, consideration should be made for gender.

Hypothesis one: *The laboratory-based method has no significant effect on Upper Basic II students' achievement in geometry.*

Table 3. One-way ANCOVA of laboratory-based method on Students' Achievement in Geometry

Sources of Variation	Sum of squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	3775.23[a]	2	1887.615	111.89	0.00	0.59
Intercept	4853.74	1	4853.74	287.72	0.00	0.65
Pre-test	243.02	1	243.02	14.41	0.00	0.08
Method	3345.33	1	3345.33	198.30	0.00	0.56
Error	2648.55	157	16.87			
Total	71468.00	160				
Corrected Total	6423.78	159				

[a.] R-Squared = .588 (Adjusted R Squared = .582)

Table 3 is a one-way between-groups analysis of covariance to evaluate the mean achievement scores of students taught geometry using laboratory-based method. The analysis reveals compelling evidence regarding the effect of the laboratory-based method on Upper Basic II students' achievement in geometry. Firstly, after adjusting for pre-test scores, a significant difference is observed between the two groups in terms of students' post-test scores, as evidenced by the obtained F-statistic of 198.30 with a p-value of 0.00, indicating statistical significance. Moreover, the substantial effect size, represented by a partial eta-squared value of 0.56, suggests that a considerable portion (56%) of the variance in achievement scores can be attributed to the laboratory-based method employed. Additionally, it is noted that although there is a statistically significant difference between pretest and post-test scores, the observed relationship between these scores is relatively weak, as indicated by a partial eta-squared value of 0.08. Considering these findings, the hypothesis suggesting that the laboratory-based method has no significant effect on students' achievement in geometry is hereby rejected. Instead, the results indicate a significant positive effect of the laboratory-based method on students' achievement in geometry.

Hypothesis two: *There is no significant difference between male and female students' achievement in geometry when the laboratory-based method is used.*

Table 4. One-way ANCOVA of gender differences in Students' Achievement in algebra

Sources of Variation	Sum of Squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	205.18[a]	2	102.59	4.67	0.01	0.09
Intercept	5949.20	1	5949.20	270.87	0.00	0.75
Pre-test	102.30	1	102.30	4.66	0.03	0.05
Gender	113.91	1	113.91	5.19	0.03	0.05
Error	1976.71	90	21.96			
Total	56424.00	93				
Corrected Total	2181.89	92				

[a]R Squared = .094 (Adjusted R Squared = .074)

Results from Table 4 show a one-way between-groups analysis of covariance to compare the mean achievement scores of male and female students taught geometry using laboratory-based method. The statistical analysis indicates that after controlling for pre-test scores, there is a significant difference between the achievement scores of male and female students. This is evidenced by the obtained F-statistic of 5.19, with an associated significance level (p-value) of 0.03, which is less than the conventional threshold of 0.05. However, it is crucial to interpret the practical significance of this statistical finding. The effect size, as measured by partial eta squared, provides insight into the magnitude of the difference observed between male and female students' achievement scores. In this case, the partial eta-squared value of 0.05 suggests that only 5% of the variance in achievement scores can be attributed to gender differences among students. Therefore, while the statistical test indicates a significant difference between male and female students' achievement scores, the effect size reveals that this difference accounts for a relatively small proportion of the overall variance in achievement scores.

The analysis further reveals that there is a weak relationship between the pretest and post-test scores in both male and female students' achievement scores, as indicated by a partial eta-squared value of 0.05. This suggests that the pretest scores do not influence the post-test scores for both genders. As a result, the hypothesis positing no significant difference between achievement scores of male and female students taught geometry using the laboratory-based method at the Upper Basic School level in the Jalingo metropolis is rejected.

Hypothesis three: There is no significant interaction effect of the method of teaching and gender on Upper Basic II students' achievement in geometry.

Table 5. One-way ANCOVA of the method of teaching and gender on Students' Achievement in Geometry

Sources of Variation	Sum of Squares	df	Mean square	F	Sig.	Partial Eta squared
Corrected Model	3896.37[a]	4	974.09	59.74	0.00	0.61
Intercept	4819.51	1	4819.51	295.57	0.00	0.66
Pre-test	257.57	1	257.57	15.80	0.00	0.09
Method	3352.90	1	3352.90	205.63	0.00	0.57
Gender	32.63	1	32.63	2.00	0.16	0.01
Method*Gender	69.40	1	69.40	4.26	0.04	0.03
Error	2527.40	155	16.31			
Total	71468.00	160				
Corrected Total	6423.78	159				

[a]R Squared = .607 (Adjusted R Squared = .596)

Table 5 shows the results of a 2 x 2 x 1 factorial analysis, examining the interactive effect of the method of teaching (laboratory-based and conventional lecture methods) and gender (male and female) on students' achievement in geometry. The statistical analysis reveals a significant interaction effect between the method of teaching and gender on students' achievement scores in geometry, as indicated by the obtained F-statistic of 4.26 with a significance level (p-value) of 0.04, which is less than the predetermined threshold of 0.05. This suggests that the combination of teaching method and gender influences students' achievement scores differently than what would be expected from the individual effects of each factor alone. Furthermore, the effect size associated with this interaction effect indicates that approximately 3% of the variance in achievement mean scores can be attributed to the combination of teaching method and gender. This suggests that, while statistically significant, the practical significance or magnitude of the interaction effect may be relatively modest, with other factors likely contributing to the variability in achievement scores among students. Therefore, the null hypothesis of no significant interaction effect of method of teaching and gender on students' achievement scores in geometry in the Jalingo metropolis is rejected.

Discussion of findings

Descriptive and inferential statistics were utilized to evaluate the effect of the laboratory-based method of teaching geometry. The method of teaching (specifically, the laboratory-based method) was designated as the independent variable, with gender acting as the moderator variable. The dependent variable of interest was the achievement scores in geometry. Data on the dependent variable was collected both before and after the experiment. Pre-treatment data, labelled as the pretest, were utilized as a covariate to adjust for initial differences both between and within the groups. Post-treatment data (post-test) were then analysed to assess the effect of the treatment. Before analysis, preliminary checks were performed to ensure that assumptions regarding normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliability of covariate measurements were not violated. These steps were essential to ensuring the robustness and validity of the subsequent statistical analyses.

This study revealed that the laboratory-based method of teaching has a substantial and beneficial effect on students' achievement in geometry. The study findings suggest that implementing the laboratory-based method results in improved learning outcomes and enhances student achievement in geometry. This discovery aligns with the findings of Ngala (2019), Anakpua, et al. (2020), David et al. (2022), as well as Bindu and Ramakrishna (2023) and Jepkosgei (2023) all of which concluded that the laboratory method of teaching improves students' comprehension and enhances their academic achievement. Specifically, the results indicate that the effect of the laboratory-based method on students' achievement is not only statistically significant but also practically meaningful. The substantial proportion of the variance in achievement scores (56%) attributed to the laboratory-based method underscores its significance in influencing student performance in geometry. These results strongly support the efficacy of the laboratory-based method in promoting enhanced learning and achievement in geometry, highlighting its importance as an effective instructional approach in educational settings. This suggests that the laboratory-based method may be more effective in promoting learning and understanding among students, leading to improved academic performance. It implies that the approach of hands-on learning, experimentation, and practical application employed in the laboratory-based method may enhance students' comprehension and retention of the material, resulting in higher achievement outcomes.

Another discovery from this study is the notable discrepancy in achievement scores between male and female students when taught geometry using the laboratory-based method. This finding, which highlights statistically significant gender disparities, echoes previous research by Busola (2011) and Asuquo and Onasanya (2006). Conversely, this finding contradicts the findings of Oludipe (2012), Ogbonne (2012), Wushishi, et al. (2016), Onuoha (2016), and Yakubu (2016), which reported no significant difference between male and female students. Furthermore, the results indicate that despite the observed statistically significant difference, the effect size, as indicated by partial eta-squared, reveals that only 5% of the variability in achievement scores can be attributed to gender differences among students. This suggests that gender differences have a relatively minor impact on overall achievement scores. In essence, the practical significance of gender in influencing achievement appears to be modest, with other factors beyond gender and pretest scores likely playing a more substantial role in explaining variations in students' achievement scores.

Upon further investigation into gender differences, it becomes apparent that there exists a significant interaction effect between the teaching method and gender regarding students' achievement scores in geometry. This finding implies that the joint influence of teaching method and gender on achievement scores deviates from the expected outcomes based solely on the individual effects of each factor. The complex interplay of individual, social, cultural, and environmental factors likely contributes to this interaction effect. Understanding these multifaceted factors can guide the development of teaching practices that are both inclusive and effective, catering to the diverse needs and abilities of all students.

CONCLUSION (KUSMAWAN, 2017, 2024)

In conclusion, the evidence suggests that implementing the laboratory-based method contributes to heightened learning outcomes in geometry, ultimately cultivating elevated student achievement. It is therefore recommended that schools and mathematics teachers consider integrating laboratory-based approaches more extensively into mathematics curricula. This could involve providing additional resources and training for educators to effectively implement laboratory-based activities in geometry instruction. Furthermore, continuous assessment and research into the specific components of the laboratory-based method that yield the most significant improvements in learning outcomes can further refine its implementation and maximize its impact on student success in geometry.

REFERENCES

Agwagah, U. N. (1997). Laboratory Approach to Mathematics I Instruction: A Situation Report on Nigerian Secondary schools in The 1990s. *Journal of Liberal Studies, 5*(2), 116-124.

Anakpua, B. C., Eze, F., & Emefo, C. N. (2020). Extent of mathematics education Laboratory usage on students' Performance in (mathematics Education) at the federal universities, South-east geo-political zone, Nigeria. *South Eastern Journal of Research and Sustainable Development (SEJRSD), 3*(1), 185-214. https://doi.org/ISSN Print: 2705-201x ISSN online: 2705-2001.

Arends, R. I. (1998). *Resource handbook. Learning to teach (4th ed.). .* Boston, MA: McGraw-Hill.

Asuquo, E. N., & Onasanya, S. A. (2006). Gender differences and students' achievement in computer technology instruction. *West Africa Journal of Educational Research , 9*(1 & 2), 1-8.

Azid, N., Hasan, R., Nazarudin, N. F., & Md-Ali, R. (2020). Embracing Industrial Revolution 4.0: The Effect of Using Web 2.0 Tools on Primary Schools Students' Mathematics Achievement (Fraction). *International Journal of Instruction, 13*(3), 711-728. https://doi.org/https://doi.org/10.29333/iji.2020.13348a

Bindu, B. H., & Ramakrishna, A. (2023). Effectiveness of Mathematics Laboratory Based Teaching Learning Programme on Academic Achievement In Mathematics of Secondary School Students, . *International Journal of Creative Research Thoughts (IJCRT), 11*(2), e86-e92. https://doi.org/www.ijcrt.org

Busola, A. J. (2011). *Gender difference in student's achievement in chemistry in secondary schools of Kakamega District, Kenya.* www.scholarsresearchlibrary.com 0n 16 – 06. https://doi.org/ www.scholarsresearchlibrary.com 0n 16 – 06

Chickering, A. W., & Gamson, Z. F. (1991). Appendix A: Seven principles for good practice in undergraduate education . *New Directions for Teaching and Learning, 1991*(47), 63-69. https://doi.org/ https://doi.org/10.1002/tl.37219914708

Dafid, D., Wibawa, B., & Situmorang, R. (2022). The Effect of Laboratory-Based Learning Strategies and Mathematic Logical Intelligence on Learning Outcomes of Linear Algebra Courses. *International Journal of Social Science Research and Review, 5*(9), 413-437 . https://doi.org/DOI: 10.47814/ijssrr.v5i9.450

Dafid, D., Wibawa, B., & Situmorang, R. (2022). The Effect of Laboratory-Based Learning Strategies and Mathematic Logical Intelligence on Learning Outcomes of Linear Algebra Courses . *International Journal of Social Science Research and Review, 5*(9), 413-437. https://doi.org/https://doi.org/10.47814/ijssrr.v5i9.450

Dienye, N. E., & Gbamannja, S. P. (1990). *Science Education, theory and Practice.* Owerri: Totan Publishers Ltd.

Elliott, S. N., Kratochwill, T. R., Littlefield Cook, J., & Travers, J. (2000). *Educational psychology: Effective teaching, effective learning (3rd ed.) . .* Boston, MA: McGraw-Hill College.

Ezeliora, R. (2001). *A guide to practical Approach to Laboratory management and safety precautions. Daughters of Divine love congregations.* Enugu: Divine Love Publishers.

Hernández-de-Menéndez, M., Vallejo Guevara, A., & Morales-Menendez, R. (2019). Virtual reality laboratory: A review of experiences. *International Journal on Interactive Design and*

Manufacturing (IJIDeM), 13(3), 947–966 . https://doi.org/https://doi.org/10.1007/s12008-019-00

Hwa, S. P. (2018). Pedagogical change in Mathematics learning: Harnessing the power of digital game-based learning. *Journal of Educational Technology and Society, 21*(4), 259–276.

I., W. D., Nasifa, A., & O., S. H. (2016). Effects of Hausa Language of Instruction on Secondary School Biology Students' Academic Performance in Sokoto State, Nigeria. *International journal of scientific research in science, engineering and techno*.

Jepkosgei, P. (2023). *Effects of laboratory method on mathematics performance and motivation among secondary school students in Kapseret sub-county, Kenya. .* M. Ed Thesis, University of Eldoret, Kenya.

Joshi, S. (2008). *Teaching of Science.* APH publishing cooperation.

Kusmawan, U. (2017). Online microteaching: A multifaceted approach to teacher professional development. *Journal of Interactive Online Learning*, *15*(1), 42–56.

Kusmawan, U. (2024). Transforming digital learning and assessment strategies in higher education. *Multidisciplinary Reviews*, *8*(1), 2025016. https://doi.org/https://doi.org/10.31893/multirev.2025016

Lugosi, E., & Uribe, G. (2020). Active learning strategies with positive effects on students' achievements in undergraduate mathematics education,. *International Journal of Mathematical Education in Science and Technology, 53*(2), 403-424. https://doi.org/10.1080/0020739X.2020.1773555

Mcleod, S. (2024, February 1). Constructivism Learning Theory & Philosophy of Education. *Simply Psychology*. From https://www.simplypsychology.org/constructivism.html#Constructivism-Philosophy

Nekang, F. N. (2016). *Principles and Practice of Mathematics Education in Cameroon. .* NEC-Yaounde. Republic of Cameroon.

Ngala, J. S. (2019). The Impact of Laboratory Based Teaching Method on Secondary Schools Biology Students' Acquisition of Science Process Skills in Littoral Region of Cameroon. *2019International Journal of Contemporary Applied Researches, 6*(12), 90-116.

Ogbonne, I. A. (2012). *Effect of Kumon teaching strategy on junior secondary school students' achievement, interest and retention in Statistics.* Unpublished M.Ed Dissertation, Department of Science Education, University of Nigeria, Nsukka.

Ojediran, I. A., Oludipe, D. I., & Ehindero, O. J. (2014). Impact of Laboratory-Based Instructional Intervention on the Learning Outcomes of Low Performing Senior Secondary Students in Physics. *Creative Education, 5*, 197-206. https://doi.org/http://dx.doi.org/10.4236/ce.2014.54029

Okigbo, E. C., & Osuafor, A. M. (2008). Effect of using mathematics laboratory in teaching mathematics on the achievement of mathematics students. *Educational Research and Review, 3*(8), 257-261. https://doi.org/http://www.academicjournals.org/ERR

Oludipe, D. I. (2012). Gender difference in Nigerian junior secondary students' academic achievement in basic science. *Journal of Educational and Social Research, 2*(1), 93 – 98 .

Omiko, A. (2017). *Job Orientation and Placement: The Role of Science Education in a Developing Economy.* Abakaliki: Larry and Caleb Publishing House.

Onuoha, C. J. (2016). *Effect of Mathematics game-based instructional techniques on students' achievements and interest in algebra at basic educational level.* Unpublished PhD thesis, University of Nigeria, Nsukka.

OpenAI. ChatGPT (3.5). (2024). *Large language model.* https://chat.openai.com.

President's Council of Advisors on Science and Technology . (2012). *Engage to excel: producing one million additional college graduates with degrees in science, technology, engineering, and mathematics.* White House Office of Science and Technology Policy. Washington (DC). https://files.eric.ed.gov/fulltext/ED541511.pdf.

Rach, S., & Ufer, S. (2020). Which prior mathematical knowledge is necessary for study success in the university study entrance phase? Results on a new model of knowledge levels based on a reanalysis of data from existing studies. *International Journal of Research in Undergraduate, 6*, 375-403. https://doi.org/https://doi.org/10.1007/s40753-020-00112-x

Rathod, V. D., & Amin, J. N. (2020). Effectiveness of Mathematics Laboratory Based Teaching Learning Programme with reference to Achievement of Standard VIII Students in Mathematics. *International Journal of Research in all Subjects in Multi Languages, , 8* (11), 17-24.

Richard, E. M. (2009). *Multi-Media Learning.* Yogyakarta: Pustaka Pelajar.

Srinivasa, N. (1978). A Laboratory for teaching mathematics. *JSTAN , 9*(1), 22-24.

Stanberry, M. L. (2018). Active learning: a case study of student engagement in college Calculus. *International Journal of Mathematical Education in Science and Technology, 49*(6), 959-969. https://doi.org/10.1080/0020739X.2018.1440328

Tambo, I. L. (2012). *Principle and methods of teaching.* Limbe. ANUCAM.

Wushishi, D. I., Nasifa, A., & O., S. H. (2016). Effects of Hausa Language of Instruction on Secondary School Biology Students' Academic Performance in Sokoto State, Nigeria. *International Journal of Scientific Research in Science, Engineering and Technology , 2*(3), 551-558.

Yakubu, K. O. (2016). *Effects of field-based teaching strategy on interest, retention and performance in climate change among secondary school students in Anchau, Kaduna, Nigeria.* Unpublished PhD thesis, Department of Science Education, Faculty of Education.