Between Students and Classroom: A Route to Performance Via Geoboard Instruction in Junior Secondary Schools Mathematics

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Abstract
This study investigated the effectiveness of Geoboard instruction on students' achievement in plane geometry at the junior secondary school level. A sample of 157 students (83 males and 74 females) was drawn from two public schools in Lagos State. The Plane Geometry Achievement Test (PGAT) was validated through face and content validity, and its reliability was confirmed using a test–retest method, yielding a coefficient of 0.79. The study adopted a quasi-experimental design, addressing three research questions and testing three hypotheses. Data were analyzed using descriptive statistics and analysis of covariance (ANCOVA) at the 0.05 level of significance. Findings revealed that students exposed to Geoboard instruction demonstrated higher participation and significantly better performance than those taught with conventional methods. The pretest [$F(1,156) = 31.60$; $p < 0.05$] and posttest [$F(1,156) = 249.41$; $p < 0.05$] results confirmed significant differences in achievement between the groups. The study concludes that Geoboard instruction enhances students' performance in plane geometry more effectively than traditional methods and recommends its integration into mathematics classrooms.

Keywords: Geoboard instruction, Plane geometry, Mathematics achievement, Teaching strategies, Junior secondary education

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Introduction

Mathematics, particularly geometry, is a core subject in junior secondary school curricula worldwide. Because of its practical applications and role in the advancement of higher mathematics, it is crucial for the development of logical reasoning and problem-solving skills. Despite being a vital subject in the curriculum, students usually find it difficult to understand the ideas of plane geometry, despite it being one of the most significant areas of mathematics. These challenges are frequently linked to a variety of factors, including teaching methods, student involvement, and the relationship between students and the classroom setting (Alhassan, Yussif & Ibrahim, 2022; Taha, Usman & Sulaiman, 2021).

In addition to individuals' natural aptitudes, classroom dynamics, and teaching strategies in junior secondary schools affect how well students succeed in plane geometry. The pedagogical approach teachers take, the use of visual aids, and the promotion of active student participation are important elements that can either positively or negatively impact geometry learning outcomes (Kieffer & Mendoza, 2023). According to research, students who actively participate in interactive, group projects that involve geometric ideas perform better academically than passive learners (Vanguard, Harris & Oran, 2020).

The classroom environment, which includes the availability of teaching tools, peer support, and teacher-student interaction, has a significant impact on how students approach studying geometry. A supportive and upbeat atmosphere can improve student performance, whereas a bad or uninteresting learning environment may have the opposite effect (McLeod & Young, 2020). Using geoboards in the classroom allows students to interact with geometric concepts in a hands-on way, which aids in their understanding of abstract ideas.

Numerous studies show that active participation in hands-on activities, such as using geoboards, helps students develop their critical thinking and problem-solving skills in addition to their conceptual comprehension (Adams & Gill, 2023). Students can gain a deeper understanding of geometric properties through geoboard training, which enables them to experiment and modify forms in ways that are not possible with traditional textbook study alone (Lee & Fang, 2022). However, the effectiveness of geoboard-based instruction will depend on how well teachers incorporate these resources into their lesson plans and encourage collaborative, student-centered learning.

Concentrating on the effects of classroom dynamics, student-teacher interactions, and the usage of the geoboard as a teaching tool on student performance. The kind of pupils who use the geoboard for instruction has no bearing on this outcome. It is also clear that it benefited every student, regardless of gender.

The gender gap in academic achievement, particularly in mathematics, has been the subject of numerous studies throughout the years. In mathematics, males have traditionally outperformed females (Lubienski & Lubienski, 2020), but more recent studies have shown that these differences are closing, particularly in settings that value gender-inclusive teaching (Lee & Byun, 2020).

Gender differences in mathematics skills can be attributed to a variety of reasons, including cultural biases, classroom dynamics, instructional methods, and resource availability (Else-Quest et al., 2020). With geoboard application, there is a unique opportunity to address these gender disparities. Because the information is interactive and visually attractive, it may be more equitable for male and female students to engage with it. Unlike traditional methods that may mostly rely on verbal and abstract explanations, geoboards offer an interactive and practical learning experience that can be equally accessible to all students, regardless of gender (Miller & Muth, 2021). Due to its active nature, geoboard-based learning has the potential to eliminate gender biases in mathematics and create a more inclusive atmosphere for students of both sexes.

The use of geoboards in the classroom contributes to gender parity by providing each student with an opportunity to engage with mathematical concepts dynamically and tangibly. Children learn best when they are actively involved in the process, especially in a kind and supportive learning environment, according to a study (Miller & Muth, 2021). Geoboard instruction may appeal to a range of learning styles since it allows students to move items, see geometric shapes, and experiment with geometric changes. Students' problem-solving skills can be enhanced by this kind of exploratory, experiential learning, regardless of gender (Schmidt & Uminska, 2022).

By using geoboard instruction, educators may foster a collaborative learning atmosphere in the classroom that recognizes and celebrates the efforts of both male and female students. Additionally, gender-equitable instruction may aid in closing the gender gap in mathematics achievement by encouraging all students to interact with difficult mathematical ideas fairly and encouragingly (Else-Quest et al. 2020). In junior secondary schools, when gender-based expectations might begin to influence students' educational paths, this kind of approach is particularly crucial. The yearly academic report has not been good throughout the years, despite every attempt to improve students' performance in mathematics.

The WAEC Annual Examiner Report reports that student performance in mathematics has not been as good as expected from 2017 (59.22%) to 2018 (54.95%), 2019 (64.18%), 2020 (65.24%), 2021 (64.42%), and 2022 (76.36%). All parties involved in the teaching and learning of mathematics are concerned because this drop in student performance has a significant detrimental effect on their ability to obtain the required learning outcomes in mathematics in general and plane geometry in particular. It has been observed that mathematics teachers do not always use the appropriate hands-on teaching strategies when doing material clarification in the classroom. This could be a reason for the observed students' consistently low academic performance on internal and external junior secondary school mathematics tests. (Okoye and Onyeka, 2022).

Numerous factors have been identified as contributing to pupils' subpar performance in mathematics on the Basic Education Certificate Examination (BECE), according to Anaeche and Ezeamaenyi (2018). A bad learning environment and antiquated equipment (Adegoke, 2013); pupils' inadequate mathematical competence (Njigwum & Oye, 2020); and a lack of comprehension of basic mathematical ideas (Nathan & Umoinyang, 2020) are some of these factors. Nonetheless, it has long been thought that the hardest subject taught in schools is mathematics (Kang, 2019). It is based on the idea that by examining these factors, the study hopes to offer recommendations for improving the use of geoboards in mathematics instruction. With an emphasis on the connection between students and their classroom experiences, this study attempts to investigate the variables affecting students' performance in junior secondary school mathematics.

Theoretical framework

This framework was analyzed in light of contemporary theories that support the methodology. Two of the numerous theoretical stances found in the literature are taken into consideration by the researchers since they are pertinent to the methodology of this investigation. The researchers use constructivist and cognitivist theoretical positions to do this. Constructivism maintains that learning is an active process in which students actively engage with new information to expand on their prior knowledge, particularly as articulated by Piaget (1976) and Vygotsky (1978).

The use of a geoboard in geometry instruction aligns with constructivist principles by allowing students to work with geometric forms, explore spatial relationships, and witness abstract concepts come to life. Geoboard exercises, a fundamental part of constructivist education, help students develop their understanding of geometric properties through hands-on research and problem-solving (Shapiro & Stein, 2020). Through this active learning process, students are prompted to draw connections between new material and their current cognitive structures, leading to improved recall and comprehension.

Vygotsky's Zone of Proximal Development (ZPD) places a strong emphasis on the importance of social contact and guided learning in the process of knowledge development. Geoboard instruction, in conjunction with peer engagement and instructor scaffolding, allows students to work inside their zone of competence (ZPD), completing tasks that they may find difficult to accomplish without help (Mercer, 2021). This collaborative environment enhances the learning process and promotes a deeper understanding of geometric concepts. Cognitive learning theory, which focuses on understanding the internal processes determining how learners acquire, organise, and retain information, offers a helpful framework for understanding how geoboard instruction can enhance junior secondary school mathematics performance.

Cognitive learning emphasises the significance of mental models, information processing, and the active construction of knowledge through experience. By providing students with a concrete and interactive way to explore, alter, and experiment with geometric notions, the geoboard is a dynamic tool that supports various cognitive processes in the context of geometry.

Students actively construct schemas or mental representations, based on their experiences and interactions with the outside world, according to cognitive learning theory (Anderson, 2021). When learning mathematics, especially geometry, students must create mental models of geometric shapes, spatial relationships, and attributes. With the use of a geoboard, students can engage with geometric objects in a tactile, visual manner that facilitates the development of these mental images.

By constructing, exploring, and altering designs with the geoboard's pegs and rubber bands, students can more effectively internalize geometric elements and relationships than they might not if they only used abstract, symbolic representations (Clements, 2021). The geoboard is a cognitive tool that makes it easier to encode and store geometric knowledge in long-term memory. As they physically construct geometric shapes and patterns on the geoboard, students create visual-spatial memories that help them remember and use those memories when they are solving issues (Sweller, 2020). These experiences enhance the learners' understanding of geometric ideas and their ability to apply them in new and varied situations by fortifying their schemas.

Plane Geometry

Understanding plane geometry, a subfield of geometry that studies the properties and interactions of geometric forms and objects on a flat surface, is essential to developing a fundamental understanding of mathematics. Junior secondary school students are taught a variety of plane geometry topics, including points, lines, angles, polygons, and transformations. More advanced mathematics courses are built upon these ideas. Students can interactively explore these concepts with the use of the geoboard, a versatile geometric tool that facilitates better understanding through real-world application.

This section discusses key concepts in plane geometry that are commonly explored in geoboard training, providing a theoretical and practical basis for understanding their importance in the learning process.

In plane geometry, the concept of a point is fundamental. A point is a location in space that has no dimensions and is the basic building block for more complex geometric structures. Lines, defined by two points that stretch infinitely in both directions, are used to construct many other geometric constructions. The geoboard is particularly useful for depicting these abstract concepts. Rubber bands can be used by students to mark locations and draw lines on the geoboard, providing them with a tactile learning experience. Students can improve their comprehension of lines, points, and by positioning the pegs to form lines and examining the relationships between different spots, they can be used as the foundation for geometric constructions (Taha et al., 2021).

An angle is formed when two lines or rays meet at a common endpoint known as the vertex. Angles are essential to understanding shapes and their properties because they specify the separation between two crossing lines. Students commonly encounter a variety of angles, including acute, right, obtuse, and reflex angles; each is crucial to geometric thinking. By fastening rubber bands between the points of the pegs on a geoboard, students can create angles. This hands-on approach helps students measure and observe the size of different angles, which enhances their ability to identify and classify angles based on their properties (Olumide et al., 2020). Geoboard instruction cultivates an intuitive understanding that transcends rote memorizing by promoting active engagement with angles.

Triangles and polygons are fundamental in plane geometry. Triangles are three-sided polygons, while polygons are closed forms with several sides. Geometric characteristics including symmetry, area, and perimeter are commonly studied using these designs. Students can use Geoboards to make a range of polygon forms, such as squares, rectangles, isosceles triangles, and equilateral triangles, by stretching rubber bands between pegs. This hands-on approach allows one to observe directly how many polygonal qualities, such as symmetry and congruence, come to life. By playing with different polygon forms on the geoboard, students can gain a better understanding of how to classify and measure them (Clements, 2021).

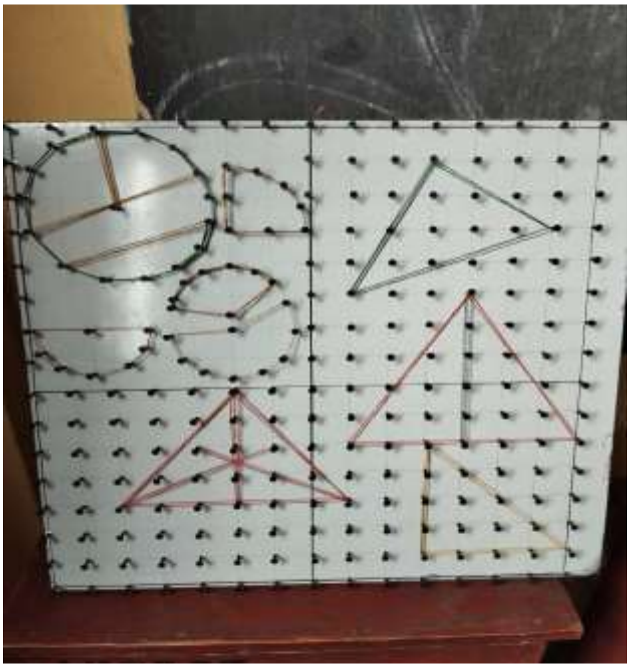

Figure 1: Sample of geo-board
Source: fieldwork 2024

However, the following research questions were generated by the study: (i) What is the mean difference in students' performance in the geoboard application classroom and those in the conventional classroom? (ii) What is the difference in the main effect of students' gender on students' performance? (iii) What is the difference in the interaction effect of teaching strategies and gender on students' performance? The study also formulates three hypotheses for this study H_{01}: There is no significant difference between the performance of students in the geoboard application classroom and those in the conventional classroom. H_{02}: There is no significant effect of students' gender on performance in the geoboard application classroom and those in the conventional classroom. H_{03}: There is no significant interaction effect of the teaching strategies and student gender on the performance of students in the geoboard application classroom and those in the conventional classroom.

Methods

Researchers use a quasi-experimental research methodology, which does not require random assignment and can assess the efficacy of educational interventions or curricula (Drits-Esser et al., 2020). Given that teaching strategies and curricula might occasionally differ, this is particularly crucial when it comes to the research design of a study in mathematics education. The quasi-experimental research approach is appropriate as the researchers were unable to completely randomize the subjects because of the demanding academic timetable. Scherer and associates (2021) used a quasi-experimental methodology to support their claim that an adaptive learning system improves students' performance in mathematics by significantly increasing their capacity to solve mathematical problems. The treatment group and the control group were the two intact groups that were used. This suggests two teaching methods (geoboard application and conventional) and two gender groups (male and female) in the mathematics classroom. Two junior secondary schools were involved; one was designated as the treatment group, and the other as the chosen school's control group. The research design's layout is displayed as follows:

O_1	X_1	O_2	(E)
O_3	X_2	O_4	(C)

Figure 2: The illustrative presentation of the research design
O_1: represents the pre-test of students in the experimental group;
O_2: represents the post-test of the students in the experimental group;
O_3: represents the pre-test of the students in the control group;
O_4: represents the post-test of the students in the control group;
X_1: represents the treatment for the experimental group (Geoboard application approach);
X_2: represents the treatment for the control group (Conventional method approach);
C: represents the control group;
E: represents the experimental group;
The pretest was used for the first observations (O_1 and O_3) in this quasi-experiment, followed by the strategy used (X_1 and X_2) in the treatment and control groups, and the posttest was used for the last observations (O_2 and O_4). In this study, the intervention process was conducted in two groups. The treatment group (E) received instruction on plane geometry principles in mathematics utilizing a geoboard instruction. A facilitator led the class in teaching the notion of plane geometry, and the facilitator used a geoboard to facilitate material engagement so that the students could better understand the principles. The conventional method was used to teach the same concepts to the control group (C). Another facilitator served as the class's anchor, teaching the idea of plane geometry through conventional means without the use of a geoboard.

Study Context, Population, Sample and Sampling Technique

Lagos State, one of Nigeria's 36 states, is home to the study population. IBILE, which stands for Ikorodu, Badagry, Ikeja, Lagos, and Epe, is the abbreviation for the five divisions that make up the 1967-created state. All junior secondary school (JSS) pupils enrolled in Lagos State's public secondary schools make up the study's population. According to the 2018–2019 annual school census data, there are 372,295 students enrolled in all 350 junior secondary schools in Lagos State. Additionally, the population consists of 190,858 female and 181,437 male students in their various schools. Based on the data collected from JSS students in Lagos State's public schools, the accessible population was understudied.

Samples were drawn from the Lagos State-dwelling study population. Ajeromi Ifelodun Local Government Area (LGA) under Education District V (Agboju) in Lagos State serves as the sample for the state's six education districts. Two intact classes (one treatment and one control group) of Junior Secondary School One (JSS 1) students from public schools in Ajeromi Ifelodun Local Government Area (LGA), Agboju District V of Lagos State, made up the study sample. Based on the selected concept for the study from the scheme of work, JSS 1 was selected for the study. Under the JSS 1 scheme of work, the subject matter was mathematical topics related to plane geometry. Convenience sampling was the method used to choose the education district among others, taking into account the researcher's location. Simple random sampling was the method used to choose Local Government from the four LGAs in the District. Simple random sampling was the method used to choose two schools from the twenty junior secondary schools. Purposive sampling was used to choose the JSS 1 students, and the teachers serving as facilitators at each school. Male (83 participants) and female (74 participants) students were involved for the two intact classes. There are 76 students in the control group and 81 students in the treatment group in this sample.

Taking this into account, the mathematics teachers in the two classrooms possess the necessary academic credentials and have similar years of experience, albeit with distinct teaching methods. While the treatment group utilized the Geoboard application, the control group was instructed to use the conventional approach. The skill levels of each group's students by gender are examined. During the study session, both teachers focused on teaching the foundations of plane geometry. The instructional guide was used to detail a plan of activities in the teaching of plane geometry in Mathematics classrooms for both experimental and control groups. The guide explained the lessons taught for four weeks which start with Properties of Plane Shapes for the first week, Perimeter of Plane Shapes for the second week, and Area of Plane Shapes for the third and fourth week. The instructional guide for the experimental group explained the steps to take in the teaching strategy while the control group explained the usual conventional method of teaching.

Instrumentation

The Plane Geometry Achievement Test (PGAT) was the instrument used in this study. The PGAT included five essay questions and 30 multiple-choice questions drawn from the ideas of plane geometry. With the intervention in between, the PGAT was given as a pretest and a posttest. It was validated by face and content validity with the assistance of some colleagues and a research study expert who carefully reviewed it and made structural corrections, adjustments, and suggestions to improve the instrument before it was finally finalized for administration. The researchers used the test-retest method to determine the reliability of the items which returned a reliability coefficient of 0.79.

Data collection

Following two weeks of training, the volunteer teacher from each school acted as a facilitator. To assess their participation in the six-week exercise, the researchers administered the pre-test to the chosen school's treatment and control groups before the intervention. In the first week, the pretest was given; the second week to the fifth week was used for the treatment; and in the sixth week, the posttest was given. Throughout the study, eight lessons, four for each school were recorded.

Data analysis

The parametric assumptions were assessed first, followed by the inferential statistics, as part of a systematic analysis of the data. Tests for parametric assumptions were performed on the data to make sure the selected inferential statistical tests were appropriate. There was no significant difference between the two groups according to Levene's test of homogeneity of variance ($F = 0.99$; $p>0.05$). The Shapiro-Wilk test of normality revealed that the data in both the treatment group ($N = 81$) = 0.97, $p > 0.05$, and the control group ($N = 76$) = 0.98, $p > 0.05$, were normally distributed. Descriptive statistics (bar chart, percentage, frequency count, averages, and standard deviation) were used to answer some of the research questions, and Analysis of Covariance (ANCOVA) was used to test the hypotheses at the significance level of 0.05.

The study participants were not randomly assigned to groups. Once these presumptions were satisfied, the student's achievement scores in both groups were analyzed using the Analysis of covariance (ANCOVA) statistics at a 0.05 significance level for hypotheses while descriptive statistics (bar chart and percentage count) were used for research questions of the study. For the ANCOVA, the pretest results were used as the covariate, the teaching strategies were regarded as the fixed factor, and the achievement scores were the dependent variable. Since the students were not randomly assigned to groups, the researchers had to apply an analysis of covariance to partially determine the impact of any initial difference between the treatment and control groups, which could have distorted the conclusions of the data. IBM-SPSS version 23 was used to analyze the data that was gathered.

Results

Research question one: What is the mean difference in students' performance in the geoboard application classroom and those in the conventional classroom?

Table 1: Mean and standard deviation of group performances in the pretest and the post-test

Index	Statistics in the Pretest		Statistics in the post-test	
	Treatment	Control	Treatment	Control
Mean	8.38	9.58	21.38	21.21
SD	3.25	3.82	4.64	5.50

Table 1 indicates that the posttest mean value for the treatment group is higher than the pretest mean, with a mean difference of 13.00. The posttest standard deviation number for the treatment group shows a similar pattern, with a change of 1.39 between the pretest and posttest. The posttest mean value for the control group is higher than the pretest mean, with a mean difference of 11.63. The posttest standard deviation number for the control group shows a similar pattern, with a change of 1.68 between the pretest and posttest.

Research question two: What is the difference in the main effect of students' gender on students' performance?

Table 2: Mean and standard deviation of group performances in the pretest and the post-test

Index	Statistics in the Pretest		Statistics in the post-test	
	Male	Female	Male	Female
Mean	8.99	8.93	21.95	20.57
SD	3.29	3.90	4.79	5.28

Table 2 indicates that the posttest mean value for the male students is higher than the pretest mean, with a mean difference of 12.96. The posttest standard deviation number for the male students shows a similar pattern, with a change of 1.50 between the pretest and posttest. The posttest mean value for the female students is higher than the pretest mean, with a mean difference of 11.64. The posttest standard deviation number for the female students shows a similar pattern, with a change of 1.38 between the pretest and posttest.

Research question three: What is the difference in the interaction effect of teaching strategies and gender on students' performance?

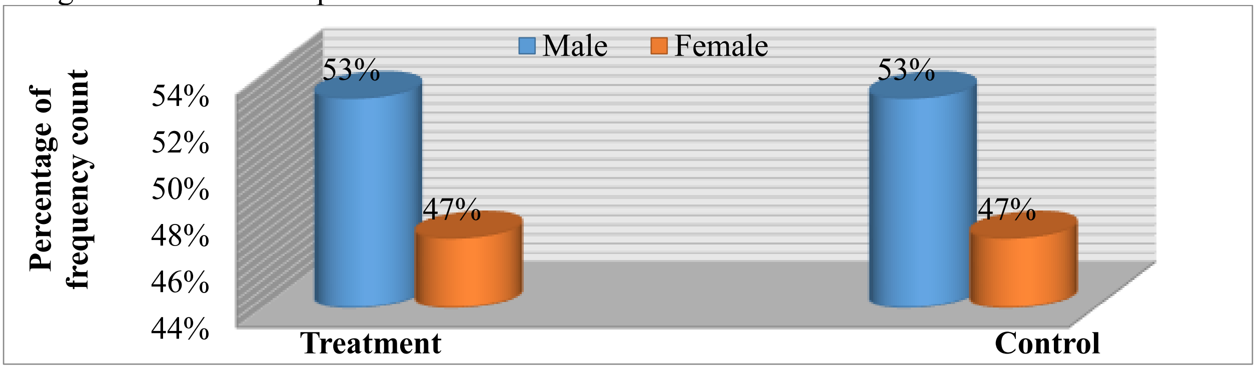

Figure 3: Interaction effect of teaching strategies and gender

In the treatment group, 43 male students had a frequency count of 53% whereas 38 female students had a frequency count of 47%, while in the control group, 40 male students had a frequency count of 53% whereas 36 female students had a frequency count of 47%. Notably, neither teaching strategies nor gender had an interaction effect on the performance of students in the geoboard application classroom compared to those in the conventional classroom, as shown by a critical examination of Figure 3 above.

Research Hypothesis One: To address the first research hypothesis, which states: that there is no significant difference between the performance of students in a geoboard application classroom and those in a conventional classroom.

Table 3: The ANCOVA of the student's performance in the treatment and control groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	750.225[a]	4	187.56	8.81	.00	.19
Intercept	5311.005	1	5311.01	249.41	.00	.62
Pretest	672.834	1	672.83	31.60	.00	.17
Total	75212.000	157				
Corrected Total	3986.930	156				

a. R Squared = .188 (Adjusted R Squared = .167)

The results indicate that there is a statistically significant difference between the performance of the students in the treatment and control groups; the pretest F-value of [F(1,156)=31.60; p<0.05] is significant at 0.00 in Table 3, and the posttest F-value of [F(1,156)=249.41; p<0.05] is also significant at 0.00 in the performance of the students in the geoboard instruction classroom and those in the conventional classroom following the interventions. The pretest mean square value is 672.83, and the posttest mean square value is 5311.01. Therefore, hypothesis one which says there is no significant difference between the performance of students in the geoboard application classroom and those in the conventional classroom is thereby rejected, that is, H_{01} is rejected.

Research Hypothesis Two: To address the second research hypothesis, which states: that there is no significant effect of students' gender on performance in the geoboard application classroom and those in the conventional classroom.

Table 4: The ANCOVA of the student's performance in the treatment and control groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	750.23[a]	4	187.56	8.81	.00	.19
Gender	69.99	1	69.99	3.29	.07	.02
Total	75212.00	157				
Corrected Total	3986.93	156				

a. R Squared = .188 (Adjusted R Squared = .167)

The gender value of [F(1,156)=3.29; p>0.05] is shown in Table 4. At 0.07, it is not significant. Thus, the hypothesis that states there is no significant effect of students' gender on performance in the geoboard application classroom and those in the conventional classroom. H_{02} is not rejected.

Research Hypothesis Three: To address the third research hypothesis, which states: that there is no significant interaction effect of the teaching strategies and students' gender on the performance of students in the geoboard application classroom and those in the conventional classroom.

Table 5: The ANCOVA of the student's performance in the treatment and control groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	750.23[a]	4	187.56	8.808	.00	.19
Gender * Group	3.45	1	3.45	.162	.69	.00
Total	75212.00	157				
Corrected Total	3986.93	156				

a. R Squared = .188 (Adjusted R Squared = .167)

The value for both gender and group [$F(1,156)=0.16$; $p>0.05$] is 0.69 and not noteworthy as revealed in Table 5. Furthermore, there appears to be minimal interaction between teaching strategy and students' gender in mathematics classrooms, as indicated by the extremely low partial eta squared (0.00). Thus, the hypothesis that states that the gender of the students and the teaching strategy do not significantly interact to affect the performance of students in geoboard application classrooms compared to those in conventional classrooms, H_{03} Is not rejected.

Discussion of results

Research question one reveals a mean difference in favour of the posttest over the pretest for both treatment and control groups. Similarly, the associated hypothesis one reveals that the students do significantly better in the Geoboard classroom than in the conventional classroom which is displayed in Table 4, the study's inferential statistics findings are based on both the pretest and posttest results. Regarding the instructional strategy used to impart the course material, it also demonstrates that, in contrast to students in conventional classrooms, students' performance in Geoboard classrooms has greatly improved. Numerous researchers have found that because Geoboard instruction enables students to freely express themselves in the classroom, it has a greater impact on students' performance in geometry classes than in conventional classrooms (Trimurtini et al., 2020; Meremikwu, 2008; Sibiya & Mudaly, 2018; Abari & Andrew, 2021). Piaget's (1973) theory, which maintains that knowledge is produced via interaction with the environment and cognitive maturation, may help to explain the large accomplishment difference between the treatment and control groups in the Geoboard application classroom. The social constructivist viewpoint also highlights the significance of meaningful learning experiences in raising student achievement. By enabling students to visualize geometric concepts, modify objects, and investigate links between geometric qualities, Geoboards provide an interesting and useful way to teach geometry. This active involvement with the subject leads to greater conceptual comprehension, which improves their academic achievement.

Research question two reveals a mean difference in favor of the posttest over the pretest for both male and female students. Similarly, the associated hypothesis two reveals that the students show that, when comparing pupils in Geoboard application classroom to those in conventional classroom, there is no significant gender difference in their performance. This implies that there are no statistically significant gender disparities in student performance between Geoboard and conventional classrooms. Meanwhile, male students did better than female students in both the treatment and control groups. This finding is supported by the possibility that male pupils, who are often believed to possess stronger altitudinal ability, may find it easier to see geometric shapes (Lloyd, 2021).

Even though male students tended to perform better on individual tasks requiring spatial manipulation, Okpala and Okpala (2022) found that male students performed better than female students in group settings that encouraged teamwork and cooperative discourse. Contrary to the results, the female students might have better verbal and social skills, which could help them work better in groups and explain geometric concepts. Research indicates that female students might do better in group settings that emphasize debate (Kaufmann et al., 2020). The social constructivism of Vygotsky (1978) places a strong emphasis on the value of social interaction and group learning in the process of knowledge development. It claims that students actively construct meaning through dialogue and shared experiences. Examining gender disparities in the context of geoboard applications as a remedial solution for flat geometry makes this theoretical approach especially relevant. Students can visually modify geometric shapes and explore geometric aspects with the use of geoboards, which promotes peer engagement and group projects. The efficiency of remedial instruction based on geoboards application can be increased by comprehending how gender affects these interactions and students' performance.

Research question three reveals neither gender nor instructional styles had an interaction effect. Similarly, the associated hypothesis three reveals that the gender of the students and the teaching methods had no discernible interaction effects on the performance of students in the geoboard application classroom compared to those in the conventional classroom. In support of this conclusion, Omotayo and Afolabi (2023) claim that while female students often participated more in conversations, male students were more likely to take the lead when designing geometric forms in mixed-gender groups using geoboards for geometry problems.

Promoting mixed-gender groups for geoboard activities is another way to create diverse learning opportunities. Mixed-gender groups, according to Eze and Osunde (2021), encourage cooperation and aid in the breakdown of conventional gender conventions, allowing students to capitalize on each other's skills. Instructional strategies like Geoboard that incorporate group projects, discussions, and practical exercises may help reduce the gender gap in performance, especially if they encourage equal participation and value all types of contributions (Okpala & Okpala, 2022). Vygotsky's ZPD places a strong emphasis on mixed-gender interactions, which allow students to exchange knowledge and engage in dialogue that challenges and refines their ideas.

Limitations

Similarly, because the students originate from diverse social, cultural, and IQ backgrounds, and because the teachers have distinct teaching philosophies, the study had to use separate classroom teachers for the two groups. Since the researchers have little control over the school administration, random sampling usually results in a disorderly classroom setting, which makes it impossible for them to accomplish their stated purpose. As part of the study limits, the program's original calendar of school activities has also been modified to make room for additional events like sports and cultural days. Above all, the researchers had taken every precaution to guarantee that the study's relevance would not be diminished by the aforementioned constraints.

Conclusion

The performance of junior secondary school students in a traditional classroom versus a classroom using a geoboard application was examined in this study. The results of the study indicate that academic success is associated with the quality of methods employed, which are believed to have a greater impact on student's performance in plane geometry. The academic results of the Geoboard classroom might be better than those of the traditional classroom because of the approach that allows for full student participation. Consequently, children in the Geoboard application classroom engage with each other without prejudice or fear.

Recommendations

The following suggestions for enhancement are offered in light of the study's findings:

i. Mathematics teachers should start engaging the students with geoboard instruction to improve their classroom interaction and performance in mathematics.

ii. Since Geoboard application has been widely recognized to help enhance meaningful learning, all primary and secondary school mathematics teachers at all levels should be familiar with its use as a teaching method.

iii. To teach instructors the fundamentals of effectively disseminating information, it is necessary to frequently host seminars or workshops that train them in modern concepts in mathematics education.

Conflict of Interest

Any possible conflicts of interest were not disclosed by the authors.

Ethical consideration

Each participant gave their informed consent by filling out a permission form attesting to their understanding of the study's objectives and the confidentiality of their responses; participation was entirely voluntary, and withdrawal was possible at any time; it is important to emphasize that subjects did not experience any physical or psychological harm or abuse throughout the research process; and it should be noted that each participant was assigned a pseudonym during the transcribing and coding procedures. The principals and other school officials granted the necessary approvals before the study started.

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