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Improving Students' Performance in Plane Geometry Through Geoboard Instruction Across Ability Levels

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Abstract

This study investigated the effectiveness of geoboard instruction in improving students' performance in plane geometry across different ability levels. The study was motivated by the persistent poor performance of students in mathematics, particularly in geometry, and the need for innovative instructional strategies capable of enhancing learning outcomes among learners with varying abilities. A quasi-experimental research design was adopted. The population was from all Lagos State Public Junior Secondary Schools. The participants consisted of Junior Secondary School students (JS 1) categorised into high, average, and low ability levels, with samples of 157 students (83 males and 74 females) chosen from two schools using a multistage sampling technique. The Plane Geometry Achievement Test (PGAT) used for data collection in this study was validated using face and content validity. The test-retest approach yielded a reliability coefficient of 0.79. There were three research questions raised and three null hypotheses were formulated and tested in the study. Descriptive statistics (mean and standard deviation) and inferential statistics (ANCOVA) were used to analyse the research questions and test the hypotheses at the 0.05 significance level, respectively. The experimental group was exposed to the geoboard instructional strategy while the control group was taught using conventional methods. Findings revealed that geoboard instruction significantly improved students' performance in plane geometry across all ability levels. The pretest F-value of [$F(1,144)=1.91$; $p>0.05$] support the assertion that there is no significant difference between the performance of students in Geoboard classroom and those in the conventional classroom before treatment while the posttest F-value of [$F(1,144)=39.92$; $p<0.05$] shows a significant difference between the performance of students in both group in favour of the treatment group while the ability level F-value of [$F(2,144)=0.39$; $p>0.05$] shows that there is no significant difference between the performance across the ability levels. The study concluded that geoboard instruction is an effective strategy for improving mathematics achievement irrespective of ability level. It was recommended that mathematics teachers integrate geoboard instructional materials into classroom practice to enhance meaningful learning.

***Keyword**: Ability level, Geoboard Instruction, Mathematics, Performance, Plane Geometry.*

Introduction

Mathematics remains a core subject essential for scientific and technological development. It is a fundamental aspect of the Junior Secondary School curriculum all over the world. Geometry is essential for the development of logical thinking and problem-solving abilities, given its usefulness in daily life and its contribution to the development of higher mathematics. Plane geometry is one of the most important areas of mathematics even though it is a crucial part of the curriculum; students frequently struggle to grasp its concepts. Building a foundational grasp of mathematics requires an understanding of plane geometry, a branch of geometry that examines the characteristics and interactions of geometric objects and figures on a flat surface. Various plane geometry topics, such as points, lines, angles, polygons, and transformations, are taught to junior secondary school students. These concepts serve as the foundation for more complex mathematical topics. With the help of the geoboard, a flexible geometric tool, students can interactively investigate these ideas, leading to a deeper comprehension through practical application.

The idea of a point is essential to plane geometry. The fundamental building block for more intricate geometric structures is a point, which is a position in space devoid of dimensions. Many more geometric structures are constructed using lines, which are defined by two points that extend eternally in both directions. When it comes to illustrating these abstract ideas, the geoboard is especially helpful. Students can use rubber bands to draw lines and indicate locations on the geoboard, giving them a tactile experience that helps them learn. Students can gain a better understanding of points, lines, and how they serve as the basis for geometric constructs by arranging the pegs to create lines and observing the connections between various points. (Taha et al., 2021).

Numerous factors, such as instructional strategies, student participation, and interactions between students and the classroom environment, are commonly associated with these difficulties (Alhassan et al., 2022; Taha et al., 2021). Despite its importance, students' performance in mathematics, particularly geometry, has remained poor (WAEC Reports, 2020–2024). Geometry is often perceived as abstract and difficult due to teacher-centred instructional approaches. Clements and Sarama (2020) emphasised that learners understand geometry better when actively engaged in exploration.Research shows that students who actively engage with geometric concepts through interactive and collaborative classroom activities score better when compared to passive learners (Vanguard, Harris & Oran, 2020). Students' approaches toward studying geometry are greatly influenced by the classroom environment, which includes the availability of teaching resources, peer support, and teacher-student contact. While a poor or disengaging learning environment may have the opposite impact, a positive and encouraging setting can boost student performance (McLeod & Young, 2020). Students can engage with geometric concepts hands-on while using geoboards in the classroom, which helps them understand abstract concepts. Manipulatives such as geoboards provide concrete experiences that support conceptual understanding. Geoboard instruction enables students to construct and visualise geometric concepts, thereby improving comprehension.

Ability level differences among students also influence learning outcomes, as high-, average-, and low-ability learners respond differently to instruction, as learner-centred strategies can reduce achievement gaps among students of varying abilities. By giving every student the chance to connect with mathematical ideas in a concrete and dynamic way, the usage of geoboards in the classroom helps promote gender parity. According to research, children learn best when they actively participate in the process, especially in a welcoming and encouraging learning atmosphere (Miller & Muth, 2021). Students can manipulate objects, perceive geometric shapes, and experiment with geometric transformations through geoboard instruction, which may appeal to a variety of learning styles. Regardless of ability level, this type of experiential, exploratory learning can improve students' problem-solving abilities.

Students’ ability is the set of mathematical skills and capacity to conceive, apply, and interpret mathematical concepts to solve problems in a variety of real-world scenarios. It includes concepts, procedures, data, and sources that can be applied to describe, elucidate, and assess phenomena. It helps people to generate the kind of sound judgments and decisions that productive, involved, and thoughtful citizens of the twenty-first century must make. It also helps people to comprehend the function that mathematics plays in the world (Sabasaje & Oco, 2023). Skills are extremely important in mathematics instruction and so, the teachers must assist students in drawing connections between the many mathematical principles and the jargon that goes along with them. Having strong mathematical skills is crucial for achieving individual work outcomes in the classroom and day-to-day activities (Ozsoy et al., 2022). The field of education is now concerned with the mathematical skills of students (Etang & Regidor, 2022). Every student has to enhance their mathematical ability, because it is a cognitive capacity that is necessary for solving difficulties involving the relationship between numerical symbols and students' cognitive activities.

Therefore, the ability to solve a problem using numerical symbols or logical reasoning is referred to as mathematical ability. (Muhammad & Angraini, 2023). Mathematics ability gaps were particularly noticeable prior to school entry and have grown over time. According to Xie et al. (2020), there are four primary components of mathematical ability which include numerical ability, arithmetic ability, geometric ability and logical ability. The acquisition of these four skills is essential for mastering mathematics, according to the assertion made by Fawziawati, (2022) that students must acquire and own their numerical ability to master mathematics. The same is true for geometric ability (Larkin et al., 2019), logical ability (Bezuidenhout & Henning, 2022), and arithmetic ability (Elofsson et al., 2018). Although having mathematical ability is crucial for understanding mathematics, students still encounter challenges in mastering the subject. According to Noto et al. (2016), students still struggle to understand issues, accurately make symbols during operations and apply mathematical concepts in everyday situations. A different study reveals that secondary school students' mathematical connecting abilities are rated as extremely low (Rahmawati et al., 2019; Siregar & Surya, 2017). The poor perfomance rate is evident in the indications of the relationships that exist between mathematical ideas and other

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scientific disciplines and between mathematical ideas and real-world issues. Anaeche and Ezeamaenyi (2018) reported several factors that have been found to contribute to students' poor performance in mathematics on the Basic Education Certificate Examination (BECE). These factors include students' low mathematical ability (Njigwum, & Oye, 2020); a poor learning environment and outdated equipment (Adegoke, 2013); and a lack of understanding of fundamental mathematical concepts (Nathan & Umoinyang, 2020). This study therefore investigates the effect of geoboard instruction on students' performance in plane geometry across ability level

Purpose of the Study

The researchers explored the effectiveness of geoboard instruction in improving students' performance in plane geometry across different ability levels.

. This study specifically explored the:

i. Difference in students' performance in the Geoboard instruction classroom and those in the conventional classroom.

ii. The main effect of ability level on students' performance in plane geometry

iii. Interaction effect of teaching strategies and ability level on students' performance in plane geometry

Research Questions

The following research questions guided this study:

i. What is the main effect of students' performance in the Geoboard instruction classroom and those in the conventional classroom?

ii. What is the main effect of students' ability level on students' performance?

iii. What is the interaction effect of teaching strategies and ability level on students' performance?

Null Hypotheses

The following hypotheses were formulated to guide the conduct of this study:

$H_0$1: There is no significant effect of treatment (Geoboard instruction) on students' performance in plane geometry.

$H_0$2: There is no significant main effect of students' ability level on performance in the Geoboard application classroom and those in the conventional classroom.

$H_0$3: There is no significant interaction effect of the teaching strategies and students' ability level on the performance of students in the Geoboard application classroom and those in the conventional classroom.

Theoretical Review

This review was examined within the framework of current theories that bolster the research approach. Out of many theoretical approaches in the literature, the researchers consider two that are relevant to the way this study is being conducted. To do this, the researchers draw on constructivist and cognitivist theoretical stances. Constructivism, especially as expressed by Piaget (1976) and Vygotsky (1978), holds that learning is an active process in which students engage meaningfully with new material to build upon their existing knowledge. By allowing students to work with geometric forms, investigate spatial relationships, and see abstract ideas come to life, the use of a geoboard in geometry instruction is consistent with constructivist ideals. A key component of constructivist learning, geoboard exercises enable students to build their grasp of geometric properties through practical investigation and problem-solving (Shapiro & Stein, 2020). Students are encouraged to make connections between new information and their preexisting cognitive structures through this active learning process, which promotes greater comprehension and memory.

The Zone of Proximal Development (ZPD), as proposed by Vygotsky, emphasizes the value of guided learning and social interaction in the process of knowledge formation. When combined with instructor scaffolding and peer participation, geoboard instruction gives students the chance to work inside their zone of proficiency (ZPD), completing activities that they might not be able to complete on their own but can complete with assistance (Mercer, 2021). This cooperative setting fosters a deeper comprehension of geometric ideas and improves the educational process. A useful framework for comprehending how geoboard training can improve junior secondary school mathematics performance is provided by cognitive learning theory, which focuses on comprehending the internal processes that affect how learners acquire, organize, and retain information. The importance of mental models, information processing, and the active creation of knowledge by experience are all highlighted by cognitive learning. The geoboard is a dynamic tool that facilitates these cognitive processes in the context of geometry by giving students a tangible and interactive means to view, manipulate, and experiment with geometric concepts.

Cognitive learning theory states that students actively create schemas—mental representations—based on their experiences and interactions with the outside world (Anderson, 2021). Students must build mental models of geometric shapes, spatial relationships, and qualities when studying mathematics, particularly geometry. Students can interact with geometric objects in a hands-on, visual way with a geoboard, which helps them create these mental representations. Students can more successfully internalize geometric features and relationships by creating, experimenting, and modifying shapes with the geoboard's pegs and rubber bands than they could by relying solely on abstract, symbolic representations (Clements, 2021). The geoboard serves as a cognitive tool that facilitates the encoding and long-term memory storage of geometric knowledge. Students develop visual-spatial memories as they physically build geometric forms and patterns on the geoboard, which makes it easier for them to recall and use those memories when solving problems (Sweller, 2020). By strengthening the learners' schemas, these experiences improve their comprehension of geometric concepts and their capacity to apply them in novel and different circumstances.

Methods

This study adopted a quasi-experimental research design involving treatment and control groups drawn from two intact classes. The study employed two teaching methods: the geoboard application method and the conventional teaching method. Students were categorised into high, average, and low ability levels based on their pre-test scores administered before the commencement of treatment to determine their prior knowledge of Plane Geometry in the mathematics classroom. Two junior secondary schools participated in the study; one school served as the treatment group, while the other served as the control group.

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) within Amuwo Odofin Division 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 JS 1 students and the teachers serving as facilitators at each school. Male (83 participants) and female (74 participants) students were selected 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 utilised the Geoboard application, the control group was instructed using the conventional approach. 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 the mathematics classroom 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 weeks. The instructional guide on 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 finalised 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; in the second week, the first lesson; in the third week, the second lesson was given; in the fourth week, the third lesson was given; in the fifth week, the fourth lesson was given; and in the sixth week, the posttest was given. Over the course of 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.

The study participants were not randomly assigned to groups. Once these presumptions were satisfied, the students' achievement scores in both groups were analysed using the Analysis of covariance (ANCOVA) statistics at 0.05 significance level for hypotheses, while descriptive statistics (mean and standard deviation) 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 analyse the data that was gathered.

Results

Students' Performance in Plane Geometry

One of the sub-themes in this study is the performance of Junior Secondary School mathematics students in Plane Geometry classes. To determine the effect of geoboard instruction on students' performance, the researcher used a quasi-experimental design during the study. A research question was developed at the outset of the study to direct the researcher in order to address the first research question, which asks: "What is the mean difference in students' performance in the Geoboard Application classroom and those in the conventional classroom?" This research question

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has an associated null hypothesis, which states that "there is no significant difference between the performance of students in the Geoboard Application classroom and those in the conventional classroom." The data on Junior Secondary School mathematics students' performance in Plane Geometry in the treatment and conventional classrooms were gathered and analysed using the Analysis of Covariance (ANCOVA), as shown in Table 3. The hypothesis is tested at the 0.05 significance level. Before that, the readers must understand how well the students in both groups performed on the pretest and posttest, which are shown in Table 1 below. It should be noted that there are 81 students in the treatment group and 76 students in the control group.

Table 1: Description of the group performances in the pre-test and the post-test

Index	Performance statistics (Pretest)		Performance statistics (post-test)	
	Treatment	Control	Treatment	Control
Mean	8.38	9.58	31.54	21.21
SD	3.25	3.82	5.68	5.50
Maximum	18.00	20.00	44.00	35.00
Minimum	1.00	1.00	18.00	6.00
Coefficient of Variation	0.39	0.40	0.18	0.26

Table 1 indicates that the mean score of the treatment group for the post-test is higher than the pre-test with a mean difference of 23.16. As outlined earlier, the participants were divided into three ability groups based on their pretest scores: high, average, and low performers. Since these students were part of groups with different ability levels, their performances were distributed according to the variables in the study.

Table 2: Mean, standard deviation and ability levels of all the participants

Group	Ability Level	Mean	Standard Deviation	N
Treatment	Low	6.66	1.69	56
	Average	11.50	1.57	22
	High	17.67	0.58	3
	Total	8.38	3.25	81
	Low	6.73	1.79	41

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Control	Average	12.00	1.75	29
	High	17.33	1.75	6
	Total	9.58	3.82	76
Total	Low	6.69	1.72	97
	Average	11.78	1.68	51
	High	17.44	1.42	9
	Total	8.96	3.58	157

According to the students' score analysis in Table 2, the treatment and control groups had 56 students (representing 69%) and 41 students (representing 54%) with low ability level, 22 students (representing 27%) and 29 students (representing 38%) with average ability level, and three students (representing 4%) and six students (representing 8%) with high ability level respectively. The low ability scores of all participants had a mean difference of 0.07, the average ability scores of all participants had a mean difference of 0.50 and the ability scores of all participants had a mean difference of 0.34.

This indicates that a greater percentage of students in the treatment group were within low ability level than those in the control group; fewer students in the treatment group were within average ability level than those in the control group; and three students in the treatment group were within high ability level and six students in the control group.

The analysis presented up to this point has been descriptive and has shown some differences and similarities between and within groups. However, the statistical significance of some of the differences that have been presented is very important, at least to the extent of the hypotheses in this study. It is in this light that the researcher conducted some statistical tests as earlier indicated. Firstly, the Analysis of Covariance (ANCOVA) was used to analyse the significance of the difference between the mean of students in the two groups. The results of the ANCOVA of the students' performances are provided in Table 3.

Table 3: The ANCOVA of the students' performances in the treatment and control groups

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4949.47[a]	12	412.46	14.55	0.00	0.55
Intercept	1487.83	1	1487.83	52.47	0.00	0.27
Pretest	54.22	1	54.22	1.91	0.17	0.01

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Volume 19, Number 1, March 2026, https://nigerianjournalsonline.org/

Group	1131.92	1	1131.92	39.92*	0.00	0.22
Ability	22.11	2	11.05	0.39	0.68	0.01
Group * Ability	67.08	2	33.54	1.18	0.31	0.02
Error	4083.51	144	28.36			
Total	119631.00	157				
Corrected Total	9032.98	156				

a. R Squared = .548 (Adjusted R Squared = .510)

From Table 3, the mean square value of the pretest is 54.22 and the posttest is 1487.83. This shows a significant difference, as the post-test mean square value is greater than the pretest mean square value of the students' performances in the treatment and control groups. The result shows that there is a statistically significant difference between the students' performances in the two groups. Further consideration of Table 3 reveals that the pretest F-value of [F(1,144)=1.91; p>0.05] is not significant. This indicates that there is no significant difference in the students' performance in geoboard instruction classroom and those in the conventional classroom at the pretest that is, before the interventions. However, the ANCOVA results also show a posttest F-value of [F(1,144)=52.47; p<0.05], which is significant. Thus, a statistically significant difference emerged between the two groups [F(1,144)=39.92; p<0.05], which is significant at p<0.05. The partial eta squared value of 0.22 suggests that 22% of the variance in students' performance in geoboard instruction classroom can be attributed to the effect of the treatment, reflecting a moderately high effect size. 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." In the following part, the researcher focuses on the students' ability levels in the mathematics classroom.

Students' Ability Levels

The impact of students' ability level on their performance was further investigated as part of the study. A research question was developed at the outset of the study to direct the researcher in this direction. The research question was: "What is the difference in the main effect of students' ability level on performance?" This also has an associated hypothesis, which states that "there is no significant effect of students' ability level on performance in the Geoboard Application classroom and those in the conventional classroom."

The data on the students' performances in the conventional classroom and the Geoboard Application classroom were pulled together and analysed using the ANCOVA, as shown in Table 3; Recall that the pretest results are used to categorise participants into three ability groups: high performers, average performers, and low performers, as explained earlier on . Table 4 shows the main effect of students' ability levels on students' performances.

Table 4: Mean value of students' ability levels in the pre-test and post-test

Index	Pre-test		Post-test	
	Treatment	Control	Treatment	Control
Low	6.66	6.73	31.00	19.20
Average	11.50	12.00	32.41	22.52
High	17.67	17.33	35.33	28.67

According to the mean value of students' ability levels in Table 4., there is a mean difference of 24.34 between pretest and posttest for students of low ability level, a mean difference of 20.91 for students of average ability level, and a mean difference of 17.66 for students of high ability level in the treatment group. Similarly, there is a mean difference of 12.47 for students of low ability levels, a mean difference of 10.52 for students of average ability levels and a mean difference of 11.34 for students of high ability levels in the control group.

The analysis presented up to this point has been descriptive and has shown some differences and similarities between and within the groups. However, the statistical significance of some of the differences that have been presented is very important, at least, to the extent of the hypotheses in this study. It is in this light that the researcher conducted some statistical tests, as earlier indicated. Secondly, the Analysis of Covariance (ANCOVA) was used to analyse the significant effect of students' ability level on performance in the Geoboard Application classroom and those in the conventional classroom. Further consideration of Table 3 shows that the ability value of [$F(2,144)=0.39$ $p>0.05$] is not significant at 0.68. Therefore, the hypothesis that says, "there is no significant effect of students' ability levels on performance in the Geoboard Application classroom and those in the conventional classroom" is thereby not rejected. In the following part, the researcher focuses on the interaction effect of teaching strategies and ability levels in mathematics classrooms.

Interaction Effect of Teaching Strategies and Ability Levels

The researcher investigated the interaction effect further to better understand how the students' performances were affected by teaching strategies and ability levels in mathematics classrooms. A research question was developed at the outset of the study to direct the researcher in this manner. It addresses the third research question, which is: "What is the difference in the interaction effect of teaching strategies and ability levels on students' performances?" There is also an associated null hypothesis to this research question, which represents the third null hypothesis formulated in this study. The hypothesis states that "there is no significant interaction effect of the teaching strategies and ability levels on the performance of students in the Geoboard Application classroom and those in the conventional classroom." The data on the students' performances in the two groups are compiled and analysed using the ANCOVA, as shown in Table 3. Analysing the interaction effect of the teaching strategies and ability levels in this study allows the researcher to elaborate more in terms of descriptive statistics.It is in this light that the researcher conducted some statistical tests as earlier indicated. Furthermore, the Analysis of Covariance (ANCOVA) was used to analyse the interaction effect of teaching strategies and ability level. It reveals that neither teaching strategies nor ability levels had an interaction effect in the treatment or control groups. Further consideration of Table 3 for the group and ability levels value of [$F(1,144)=1.18$; $p>0.05$] is not significant at 0.31. Additionally, the partial eta squared (0.02) is extremely low, suggesting that "there is little interaction between teaching strategies and students' ability levels in mathematics classrooms". Therefore, the hypothesis that says "there is no significant interaction effect of the teaching strategies and ability level in the treatment and control groups" is thereby not rejected.

Discussion of results

The research question one reveal a mean difference in favour of posttest over pretest for both treatment and control groups. Similarly, the associated hypothesis one reveals that the students do significantly better in Geoboard classroom than in conventional classroom which are displayed in Table 3, the study's inferential statistics findings and 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 (Meremikwu, 2008; Sibiya & Mudaly, 2018; Trimurtini et al., 2020; Abari & Andrew, 2021). Piaget's (1936) 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 classroom. The social constructivist viewpoint also highlights the significance of meaningful learning experiences in raising student achievement. By enabling students to visualise 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 a greater conceptual comprehension, which improves their academic achievement.

The mean scores of students in low, average and high levels were found to differ significantly in the treatment and control groups, based on descriptive statistics in Table 2. The results of this study's inferential statistics, which are shown in Table 3, indicate that there is no significant effect of students' ability levels on performance in the Geoboard classroom compared to those in the conventional classroom. This suggests that the ability level in student performance between the Geoboard and conventional classrooms is not statistically significant. In the meantime, the students in the treatment group outperformed their counterparts in the control group. As shown in Table 2, which displays the students' performance with their ability levels, the treatment group outperformed the control group students with low ability levels, the control group outperformed the treatment group students with average ability levels, and the control group outperformed the treatment group students with high ability levels.

The high-ability students are good in tasks demanding higher-order thinking and spatial manipulation, such as those in plane geometry, because they typically have well-developed cognitive structures and can absorb new knowledge fast and efficiently (Age & Machaba, 2025). As a result of this, it helps the students to perform better in geometry and their interactions with geoboards become largely reinforced prior knowledge, rather than greatly enhancing it. On the other hand, students with lower ability levels find it difficult to relate to abstract ideas, which could make it harder for them to comprehend geometric relationships and hence, mentally manipulate shapes. Students of this category frequently benefit from the hands-on nature of geoboards, which enable them to physically construct and manipulate geometric shapes, thereby improving their spatial reasoning and comprehension of geometric concepts (Abdussakir et al., 2022).

According to the Cognitive Learning Theory, high-ability students can process information more fully and learn more effectively when given more difficult and complicated tasks (Sweller, 2020). These students can be given increasingly difficult geometric assignments, like investigating transformations, symmetry, and polygon attributes, using geoboards. Students perform better overall in plane geometry when they engage at this level because it helps them reinforce their mastery of complex ideas and encourages higher-order thinking. For students with lower ability levels, geoboards can help close the gap by offering a tangible learning aid. These students can externalise their cognitive processes by working with tangible shapes on the geoboard, which makes abstract ideas easier to understand. This is consistent with Piaget's (1976) theory of cognitive development, which postulates that students need varying forms of assistance to understand abstract ideas depending on their cognitive maturity levels.

In the context of the social constructivist perspective, students' ability levels are dynamic and impacted by their social learning environment, rather than fixed. The Zone of Proximal Development (ZPD), as defined by Vygotsky (1978), is the space between what a student can accomplish on their own and what they can accomplish with help from a teacher or a more experienced peer. The ZPD is an important idea for students of all ability levels because it implies that learning can be maximised when students are given the right kind of support when interacting with adults and peers who have more experience. As revealed in the earlier part of this study, the frequency counts on low ability level, followed by average ability level students and high ability level students. The study further revealed that the frequency count of low ability level students in the treatment group is more than their counterparts in the control group, while the frequency count of average and high ability level students in the control group is more than their counterparts in the treatment group, respectively. The inferential statistics findings on this study as presented in Table 3 reveals that there is no significant interaction effect of the teaching strategies and ability level on the performance of students in the geoboard instruction classroom and those in the conventional classroom.

According to Dewi and Rini (2023), lower-ability students benefitted from the interaction with more than their peers, and higher-ability students increase their understanding by sharing their ideas with others. Peer interaction can enhance the social aspect of learning and create a more inviting environment in the classroom. In a social constructivist classroom, the teacher is essential in helping students of different skill levels. Teachers who carefully plan group projects and place students in mixed-ability groups can promote a collaborative learning environment. This guarantees that lower-ability students can take advantage of the knowledge and peer assistance of higher-ability students (Kaufmann et al., 2020).

In supporting this finding, Mitchelmore and White (2021) affirmed that through active engagement, students can correct misconceptions and improve their knowledge as they work with geoboards, which provide instant feedback on their actions and whether the shapes they create accurately represent the geometric concepts being studied. Facilitating collaborative learning, a crucial aspect of Cognitive Learning Theory, is one of the main advantages of geoboard-based learning. Students can converse, share their thought processes, and gain from peer criticism through collaborative learning. Both sets of students can gain knowledge from this exchange and improve their comprehension of the subjects being covered. This supports Vygotsky's (1978) theory that learning is a social process in which engaging with peers, who possess greater information, promotes cognitive development.

Limitations

In a similar vein, the study constraints include the involvement of different classroom teachers for the two groups because they have different teaching philosophies and because the students come from different social, cultural, and intelligence quotient backgrounds. Random sampling typically causes the classroom environment to become disorganised, which makes it impossible for the researchers to achieve their intended goal because they have no control over the school administration. The school activities that were initially scheduled in the program have also been changed to accommodate extra events like sports and cultural days as part of the study constraints. Above all, the researchers had taken all possible care to ensure that the limitations described above would not diminish the significance of the study.

Conclusion

The study looked at junior secondary school students' performance in a conventional classroom and in a geoboard application classroom. The study's findings show that academic achievement is linked to the caliber of approaches used, which are thought to have a bigger influence on students' performance in plane geometry. Because of the method that enables complete student participation, the academic outcomes of the Geoboard classroom may be superior to those of the conventional classroom. As a result, students in the Geoboard classroom interact with one another without bias or fear. Across ability levels, geoboard instruction improved performance of high-, average-, and low-ability students. The strategy particularly benefited low-ability learners by making abstract concepts concrete and understandable.

Recommendations

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

i. Mathematics teachers should adopt geoboard instruction to improve their classroom interaction and improve students’ performance.

ii. Schools should provide Geoboard materials, and secondary school teachers at all levels should be familiar with its use as a teaching materials.

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.

iv. Teachers of mathematics should deem it necessary to consider Geoboard instruction in the classroom since its’ beneficial across different ability levels.

Conflict of Interest

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

Ethical consideration

Before the study began, the necessary approvals were given by the principals and other school officials. Each participant provided their informed consent by completing a permission form attesting to their understanding of the study's objectives and the confidentiality of their responses. Because participation was completely voluntary, withdrawal was available at any time. It is important to stress that subjects did not suffer any physical or psychological harm or abuse throughout the research process.

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