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Effect of Process-Oriented Guided Inquiry Learning on Metacognitive Skills and Performance in Geometry among Secondary Students in Kaduna State, Nigeria

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Abstract

This study examined the effect of Process-Oriented Guided Inquiry Learning (POGIL) on metacognitive skills and performance in geometry among secondary school students in Kaduna State, Nigeria. A quasi-experimental design was employed, involving 131 SS2 students from two public senior secondary schools in Zaria Educational Zone. The experimental group (n=62) were taught geometry using POGIL, while the control group (n=69) were taught lecture method. Data were collected using the Geometry Performance Test (GPT) and Metacognitive Skills Inventory (MSI), validated and tested for reliability (r = 0.84 and α=0.85 respectively). Data were analyzed using descriptive statistics and Analysis of Covariance (ANCOVA) at 0.05 significance level. The experimental group showed significantly higher post metacognitive skills scores (M=57.29, SD=15.20) than in the control group (M=42.97, SD=9.52). Similarly, the experimental group reveals a significantly higher post-test scores (M=55.29, SD=19.06) compared to the control group (M=39.12, SD=13.61) in geometry performance. POGIL demonstrates positive effects on students' geometry performance and metacognitive skills at $F(1, 128) = 40.21$, $p < .001$. In addition, the findings reveals a significant effect of POGIL on students' Post-Performance scores, at $F(1, 128) = 31.061$, $p < .001$. The findings, reveals no significant gender differences were found in either metacognitive skills, or performance scores. This results shows that POGIL is gender friendly. The findings support the adoption of inquiry-based pedagogical approaches.

Keywords: POGIL, metacognitive, performance, metacognitive skills, geometry.

1 Introduction

Mathematics occupies a central position in secondary education in Nigeria because of its relevance to scientific reasoning, technological development and everyday problem solving. Mathematics as a tool to compute and conceptualize relationship among variables in science is an important tool in nation building. It can also be viewed as the pillar of all knowledge (Oribhabor, 2024). However, students' difficulties in mathematics remain an important concern, particularly in areas requiring conceptual understanding, strategic reasoning and problem solving. Geometry is one such area because successful problem solving requires students to interpret geometric information, select appropriate theorems and procedures, monitor their reasoning, and evaluate the validity of their solutions. Studies have reports that students have experienced difficulties in conceptualising appropriate strategies, interpreting geometric problems and applying relevant geometric theorems (Yuce et al., 2026). Academic performance can be defined as the level of an individual growth in a test when compared with the scores of others of the same level Achino (2002). Over the years the academic performance of senior secondary students in mathematics has been poor in both internal and external examinations. Mathematics in general has been seen as a difficult subject. Studies have shown that employing the right pedagogical strategies have positive effects on students learning and performance (Yohanna, 2017).

One possible explanation for students' difficulties is the predominance of teacher-directed approaches that may provide limited opportunities for learners to actively construct knowledge, explain their reasoning and monitor their own learning. The current study therefore identifies the need for instructional approaches that provide students with opportunities to explore mathematical ideas, collaborate with peers and take greater responsibility for learning (Siti, et al., 2025; Wang & Sperling, 2020). Geometry is considered to be one of the most fundamental and crucial area in mathematics, which plays a significant roles in developing various cognitive and problem-solving skills among students. However, the conventional teaching methods that focus on lecture-based instruction have been found to be inadequate in facilitating wider

understanding of geometric concepts among secondary school students. As a result, there has been increasing focus on incorporating and implementing innovative and interactive pedagogical approaches that can improve the learning outcomes of students.

One of such approaches is the Process-Oriented Guided Inquiry Learning (POGIL) method is a student-centered, inquiry-based pedagogical approach emphasizing active engagement and collaboration. Rooted in constructivism, POGIL can enhance metacognitive skills and performance across subjects, including Geometry (Abbas et al., 2019; Rodríguez-Hoyos, et al., 2019; Fediuk et al., 2018). Studies on POGIL-based geometry instruction show significant effects on secondary students' learning and performance (e.g., Belay, et al., 2026; Jeong et al., 2020). Shadburn et al. (2018) found POGIL significantly improved conceptual understanding of geometry and application to real-world situations. Pedagogical strategies differing from traditional lectures positively affect geometry learning and achievement (Bitrus et al., 2020; Garba & Salim, 2020). All inquiry-learning models generally derive from the first learning cycle model, developed using Piaget's theories. This cycle has three phases: exploration, concept invention, and application (Pedaste, et al., 2015). In POGIL, peer-led guided inquiry is central; questions progress from easier to more difficult, helping students acquire basic process skills (Moog & Spenser, 2008). Teachers act as facilitators, intervening only when requested to ensure scientific concepts are appropriately structured.

Metacognition, coined by Flavell in the 1970s, means "thinking about thinking" (Flavell, 1979, p.906) and refers to reflecting on one's own thinking processes. POGIL encourages metacognitive skills by enabling students to reflect on reasoning, identify misconceptions, and self-correct. Geometry concepts allow analytical thinking and application of theorems. Definitions include: knowledge and control children have over their own thinking and learning, awareness and management of one's own thought (Kuhn & Dean, 2004, p.270). Metacognitive skills are generally learned later in development and can often be stated by users. Metacognitive knowledge is crucial for efficient independent learning, fostering forethought and self-reflection. Metacognition consists of knowledge of cognition and regulation of cognition. Learners show increased self-confidence when building metacognitive skills; self-efficacy improves motivation and learning success. In a study that compared whether mathematical and metacognitive connection abilities were influenced by the POGIL model or not as seen from AQ, it was found that students who used the POGIL learning model had better mathematical and metacognitive connection abilities and skills than students who used the Direct Instruction learning model (Triani et al., 2025). POGIL on metacognitive awareness positively impacts learning outcomes (Gabel & Sherwood, 2015).

Gender refers to socially/culturally constructed characteristics associated with males and females (Stark, et al., 2020). Low numbers of women in science-related professions have improved, but girls' attitudes toward mathematics influence their lack of participation in science careers (Oaks, 2000). Studies on gender and mathematics learning (e.g., Fierros, 1999; Johnson, 2000) found no significant achievement differences between boys and girls. However, other studies found differences in mean scores of male and female students taught geometry using metacognitive approaches (Bitrus et al., 2020; Essien & Ado, 2017). Meanwhile, previous studies examined inquiry-oriented and POGIL-based approaches, but further investigation is needed in secondary-school Geometry within the Nigerian context, particularly regarding metacognitive skills and Geometry performance in Kaduna State. Evidence on whether responses to POGIL differ by gender remains inconclusive. This study examines POGIL in relation to metacognitive skills and performance in Geometry among Senior Secondary II students in Zaria Educational Zone, Kaduna State, Nigeria, comparing POGIL with conventional instruction and examining gender differences among students exposed to POGIL. In specific terms, we raised and addressed the following research questions in this study:

1. What is the difference in the mean metacognitive skills scores of students taught Geometry using POGIL and those taught using the conventional method?
2. What is the difference in the mean performance scores in Geometry between students exposed to POGIL and those exposed to the conventional method?
3. Is there any difference in the mean metacognitive skills scores of male and female students taught Geometry using POGIL?
4. Is there any difference in the mean performance scores of male and female students taught Geometry using POGIL?

2 Literature Review/Theoretical Framework

The study is anchored in constructivist learning theory, which views learners as active participants in the construction of knowledge. Rather than receiving knowledge passively, learners develop understanding by connecting new experiences with prior knowledge, interacting with learning materials and other learners, and reflecting on their experiences. The constructivist perspective is therefore consistent with instructional approaches that provide opportunities for exploration, collaboration and guided discovery. Peer learning theory of Piaget (1977) and social learning theory of Vygotsky (1978) the constructivism is a school of thought that believe in learners actively constructing their own knowledge and understanding using previous knowledge and interacting with instructional materials under the guidance of the teacher. Constructivism is a theory based on observation and scientific study about how people learn (Piaget, 1977). It is said that people construct their own understanding and knowledge of the world through experiencing things and reflecting on those experiences. When we encounter something new, we have to reconcile with our previous ideas and maybe by changing what we believe, or by discarding the new information as irrelevant. In any case, learners are active creator of their own knowledge. The theory of Piaget (1998) also suggested that through the process of assimilation and accommodation, individuals construct new knowledge from their experience into already existing framework without changing that framework. Piaget found that children needed to discuss their findings as well as having stimulating environment in which they can learn in pairs.

POGIL reflects these principles through structured inquiry activities in which students work collaboratively to explore concepts, identify relationships, construct explanations and apply emerging knowledge to new situations. The teacher serves primarily as a facilitator who guides students' learning rather than providing all solutions directly. The constructivist perspective also provides a theoretical explanation for the expected relationship between POGIL and metacognitive skills. When learners are required to explain their reasoning, compare ideas, monitor their understanding and revise misconceptions, they engage in processes associated with metacognitive regulation. Thus, the theoretical proposition underlying the study is that structured guided inquiry and collaborative learning may provide conditions that support both conceptual learning and metacognitive development. Based on this tenet of constructivism, the study examines the effect of POGIL on metacognitive skills and performance in Geometry among secondary school students in Zaria Educational Zone Kaduna state Nigeria.

3 Materials and Methods

3.1 Research Design

A quasi-experimental pretest-posttest non-equivalent control-group design was employed. The design involved an experimental group taught POGIL and a control group taught using the conventional method. Pretest measures of metacognitive skills and Geometry performance were obtained before treatment, while corresponding posttests were administered following the intervention.

3.2 Participants

The design of this study is pretest posttest non-equivalence quasi-experimental control group design. The population consists of 62,072 public Senior Secondary II students in Zaria Educational Zone, Kaduna State, Nigeria from which two public senior secondary schools were selected for the study, yielding a total sample of 131 students comprising 62 for experimental group and 69 in the control group. The experimental group consisted of 30 male and 32 female students while the control group comprised of 38 male and 31 female students. The sample technique was multi-stage. This involved a purposive sampling of two public secondary schools based on accessibility and availability of resources. The second stage involved a simple random sampling (balloting) technique to select the specific classes and assigned experimental and control group.

3.3 Research Instruments

Two research instruments were adapted and used by the researcher in this study namely, Geometric Performance Test (GPT) and Metacognitive Skills Inventory (MSI). The GPT was used to assess students' performance in Geometry. The instrument comprised 30 multiple-choice items adapted from West African Examination (WAEC) past questions covering plane Geometry and Circle Geometry. Each item contained four options, with one correct answer and three distractors. The test was administered within 45 minutes. The MSI was adapted from Schraw and Dennison's (1994)

Metacognitive Awareness Inventory. The instrument comprised 30 self-report items rated on a five-point Likert scale ranging from 5 (Strongly Agree) to 1 (Strongly Disagree). Higher total scores represented higher levels of reported metacognitive skills.

The GPT and MSI were subjected to expert review for content relevance, clarity, ambiguity and suitability for the target students. Three experts from the Faculty of Education at Ahmadu Bello University, Zaria, reviewed the instruments. The instruments were subsequently pilot-tested among 52 SS II students from two schools outside the main study sample. Reliability analysis produced a test-retest coefficient of $r = .84$ for the GPT and a Cronbach's alpha coefficient of $\alpha = .85$ for the MSI. These coefficients indicated acceptable internal consistency for the purposes of the study (Zakariya, 2022).

3.4 Procedure for Data Collection

The study was conducted over six weeks, comprising twelve 45-minute sessions. Prior to the intervention, research assistants were trained on administering the instruments (GPT & MSI) and on implementing both the POGIL and conventional instructional methods to ensure fidelity. Both the experimental and control groups completed the GPT and MSI as pretests before the intervention began. The intervention lasted six weeks. Both groups were taught for the same duration and covered identical Geometry content. The experimental group received instruction using Process-Oriented Guided Inquiry Learning (POGIL), while the control group received conventional lecture-based instruction. The experimental group was taught Geometry using POGIL, with each lesson structured around the exploration–concept invention–application cycle. The step-by-step process for each session was as follows:

Step 1: Formation of Collaborative Groups. Students were assigned to small, heterogeneous groups of five members each. Each group member was given a specific role (e.g., Manager, Recorder, Presenter, Strategist) to promote interdependence and accountability.

Step 2: Distribution of Guided Inquiry Activities. The teacher provided each group with a structured learning activity sheet designed to guide students through the exploration of a specific Geometry concept (e.g., properties of triangles, circle theorems, or coordinate geometry).

Step 3: Exploration Phase. Students worked collaboratively on the activity, examining patterns, manipulating geometric figures, and answering guiding questions. During this phase, the teacher circulated among groups, serving primarily as a facilitator by monitoring group activities, asking probing questions, and providing clarification only when necessary, without giving direct answers.

Step 4: Concept Invention Phase. Through group discussion and analysis of their exploration, students were guided to articulate the underlying geometric principle or formula. They constructed their own understanding of the concept, which they recorded in their activity sheets.

Step 5: Application Phase. Groups applied the newly invented concept to solve related problems or complete additional exercises. This phase reinforced understanding and allowed students to transfer their knowledge to new contexts.

Step 6: Whole-Class Debrief and Closure. The teacher facilitated a whole-class discussion where group Presenters shared their findings and solutions. The teacher synthesized the key concepts, corrected any misconceptions, and connected the day's learning to broader Geometry objectives.

The control group received teacher-directed instruction involving explanation of concepts, worked examples, and conventional classroom activities.

At the end of the six-week intervention, both groups completed the GPT and MSI as posttests to measure changes in Geometry performance and self-efficacy.

3.5 Procedure for Data Analysis

Data were analyzed using descriptive statistics (Means and standard deviations were calculated to answer the research questions). Descriptive statistics, including means and standard deviations, were used to summarize students' pretest and posttest scores. Analysis of covariance (ANCOVA) was used to examine differences between instructional groups and between male and female students exposed to POGIL while controlling for corresponding pretest scores. Prior to interpreting the ANCOVA results, the assumption of homogeneity of regression slopes was examined using the

interaction between the grouping variable and the corresponding pretest covariate. Because the interaction terms were not significant for the four analyses, the assumption was considered satisfied. The final ANCOVA models therefore included the grouping variable and the corresponding pretest score as predictors of the posttest score. Statistical significance was evaluated at $\alpha = .05$, and partial eta squared was used to report effect size. Statistical Package for Social Sciences (SPSS) Version 20.0 was used for all analyses. Ethical approval was obtained from the Kaduna State Ministry of Education. Permission was sought from the principals of participating schools. Informed consent was obtained from parents/guardians. Students were assured of confidentiality and their right to withdraw without penalty.

4 Results

4.1 Addressing the Research Question 1

Descriptive statistical analysis was carryout on the generated dataset in order to find out if there is mean difference in metacognitive skills on both experimental and control group students. The results of this analysis are presented in Table **1**.

Table **1**

Descriptive statistics on the impact of POGIL on students' metacognitive skills datasets

Performance	**N**	**Pre-Test Mean**	**STD**	**Post-Test Mean**	**STD**	**Mean ($\overline{X}$) Diff. Within Group**
POGIL	62	42.79	10.22	57.29	15.20	14.50
Conventional	69	40.26	6.83	42.97	9.52	2.71
Mean ($\overline{X}$) Diff. Between Groups		2.53		14.32		

Table 1 shows that the pre-test metacognitive skills mean and standard deviation of the experimental group were 42.79 and 10.22 respectively and their post-test mean and standard deviation were 57.29 and 15.20 respectively. In the control group, the pre-test metacognitive skills mean and standard deviation were 40.26 and 6.83 respectively, while their post-test metacognitive skills mean and standard deviation were 42.97 and 9.52 respectively. The metacognitive skills mean between the two groups shows that the pre-test has a difference of 2.53 while the mean difference within group in the post-test was 14.32. In order to determine whether the observed mean difference between the experimental and control posttest metacognitive datasets is significant, we subjected the generated dataset to ANCOVA using the pretest scores as a covariate. The results of this analysis are presented in Table **2**.

Table **2**

*ANCOVA (F-test) on the effect of POGIL on students' metacognitive skills in geometry***.**

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	6782.934[a]	2	3391.467	21.533	.000	.252
Intercept	11324.039	1	11324.039	71.900	.000	.360
Group	6333.551	1	6333.551	40.214	.000	.239
Pre-Test	86.963	1	86.963	.552	.459	.004
Error	20159.753	128	157.498			
Total	351151.000	131				
Corrected Total	26942.687	130				

a. R Squared = .252 (Adjusted R Squared = .240)

The result in Table **2** showed a statistically significant effect of instructional group on students' post-metacognitive skills scores, at $F(1, 128) = 40.21$, $p < .001$, partial $\eta^2 = .239$. The effect size, partial $\eta^2 = .239$, indicates that approximately

23.9% of the variance in post-metacognitive skills scores, after controlling for pre-metacognitive skills, was associated with instructional group.

Since the obtained p-value of < .001 is less than the 0.05 level of significance, the null hypothesis HO_1 is rejected. It is therefore concluded that there is a statistically significant difference in the mean metacognitive skills scores of students taught Geometry using POGIL and those taught using the Conventional Method, after controlling for pre-metacognitive skills. The direction of the adjusted means indicates that the difference favours students taught using POGIL. This shows that the use of POGIL strategy in teaching geometry has a positive effect on students' metacognitive skills.

4.2 Addressing the Research Question 2

Descriptive statistical analysis was carryout on the generated dataset in order to find out if there is mean difference in performance on both experimental and control group students. The results of this analysis are presented in Table **3**

Table **3**

Descriptive statistics on the impact of POGIL on students' performance scores in Geometry

Performance	**N**	**Pre-Test Mean**	**STD**	**Post-Test Mean**	**STD**	**Mean ($\overline{X}$) Diff. Within Group**
POGIL	62	37.94	12.37	55.29	19.06	17.35
Conventional	69	36.58	10.63	39.12	13.61	2.54
Mean ($\overline{X}$) Diff. Between Groups		1.36		16.17		

The result in Table **3** shows that the pre-test performance mean and standard deviation of the experimental group were 37.94 and 12.37 respectively and their post-test mean and standard deviation were 55.29 and 19.06 respectively. In the control group, the pre-test performance mean and standard deviation were 36.58 and 10.63 respectively, while their post-test performance mean and standard deviation were 39.12 and 13.61 respectively. The performance mean between the two groups shows that the pre-test and post-test has a difference of 1.36 and 16.17 respectively while the mean difference within group in the post-test was 17.35. In order to determine whether the observed mean difference between the experimental and control posttest metacognitive datasets is significant, we subjected the generated dataset to ANCOVA using the pretest scores as a covariate. The results of this analysis are presented in Table **4**.

Table **4:**

ANCOVA (F-test) on the effect of POGIL on students' performance in geometry.

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**p-value**	**Partial Eta Squared**
Corrected Model	8626.325[a]	2	4313.162	15.923	<.001	.199
Intercept	22285.110	1	22285.110	82.269	<.001	.391
Group	8413.816	1	8413.816	31.061	<.001	.195
Pre-test	83.042	1	83.042	.307	.581	.002
Error	34672.805	128	270.881			
Total	329865.000	131				
Corrected Total	43299.130	130				

a. R Squared = .199 (Adjusted R Squared = .187)

The result in Table **4** showed a statistically significant effect of instructional group on students' Post-Performance scores, at $F(1, 128) = 31.061$, $p < .001$, with the effect size partial $\eta^2 = .195$, indicates that approximately 19.5% of the variance in post-performance scores, after controlling for pre-test, was associated with instructional group. Since the obtained p-value of < .001 is less than the 0.05 level of significance, the null hypothesis HO_2 is rejected. It is therefore concluded

that there is a statistically significant difference in the mean performance scores of students taught Geometry using POGIL and those taught using the Conventional Method, after controlling for pre-test.

4.3 Addressing the Research Question 3

Descriptive statistical analysis was carryout on the generated dataset in order to find out if there is mean difference in metacognitive skills of male female of experimental group students. The results of this analysis are presented in Table **5**

Table **5**

Descriptive statistics on the impact of POGIL on students' metacognitive skills in Geometry based on Gender

Metacognitive Skills	**N**	**Pre-Test Mean**	**SD**	**Post-Test Mean**	**SD**	**Mean ($\overline{X}$) Diff. Within Group**
Male	30	42.13	11.68	55.33	16.52	13.20
Female	32	48.81	8.89	59.12	13.86	10.31

Table **5** reveals that the pre-test metacognitive skills mean and standard deviation of male of the experimental group were 42.13 and 11.68 respectively and their post-test mean and standard deviation were 55.33 and 16.52 respectively. While the female of the experimental group, has a pre-test metacognitive skills mean and standard deviation of 48.81 and 8.89 respectively. In addition, the post-test metacognitive skills mean and standard deviation of the female students were 59.12 and 13.86 respectively. The metacognitive skills mean within the group in the post-test experimental group shows that the male gains 13.20 while female gains 10.31. In order to determine whether the observed mean difference between the experimental and control posttest metacognitive datasets is significant, we subjected the generated dataset to ANCOVA using the pretest scores as a covariate. The results of this analysis are presented in Table **6**

Table **6**

ANCOVA of the effect of POGIL on students' Metacognitive skills in geometry based on Gender

Source	**Type III Sum of Squares**	**Df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Corrected Model	344.466[a]	2	172.233	.739	.482	.024
Intercept	7659.104	1	7659.104	32.883	.000	.358
Gender	115.150	1	115.150	.494	.485	.008
Pre-test	121.859	1	121.859	.523	.472	.009
Error	13742.308	59	232.920			
Total	217582.000	62				
Corrected Total	14086.774	61				

a. R Squared = .024 (Adjusted R Squared = -.009)

Table **6** shows that F (1, 59) = 0.494, with P = 0.485 and $n^2\rho = 0.008$ within the experimental groups at P < .05. The F-test statistics with F=0.494 and p=0.485, at P > .05. This means that the null hypothesis HO_3, which says there is no significant difference between the male and female students' Metacognitive Skills scores in geometry of POGIL is retained. Hence we reject the alternative hypothesis (Hα) that there is significant difference in male and female students' Metacognitive skills scores taught geometry using POGIL. This result shows that the use of POGIL strategy in teaching geometry has no statistically significant difference between male and female students' metacognitive skills scores.

4.4 Addressing Research Question 4

Descriptive statistical analysis was carryout on the generated dataset in order to find out if there is mean difference in performance of male female of experimental group students. The results of this analysis are presented in Table **7**

Table **7**

Descriptive statistics on the effect of POGIL on students' performance in Geometry based on Gender

Performance	N	Pre-Test Mean	SD	Post-Test Mean	SD	Mean ($\overline{X}$) Diff. Within Group
Male	30	35.80	12.46	55.47	18.95	19.67
Female	32	39.94	12.13	55.13	19.46	15.19

Table **7** reveals that the pre-test mean performance and standard deviation of male of the experimental group were 35.80 and 12.46 respectively and their post-test mean and standard deviation were 55.47 and 18.95 respectively. While the female of the experimental group, has a pre-test mean performance and standard deviation of 39.94 and 12.13 respectively. The performance mean within the group in the post-test experimental group shows that the male gains 19.67 while female gains 15.19. In order to determine whether the observed mean difference between the experimental and control posttest metacognitive datasets is significant, we subjected the generated dataset to ANCOVA using the pretest scores as a covariate. The results of this analysis are presented in Table 8

Table **8**

ANCOVA of the effect of POGIL on students' mean performance in geometry based on Gender

Source	Type III Sum of Squares	Df	Mean Square	F	p-value	Partial Eta Squared
Corrected Model	989.200[a]	2	494.600	1.379	.260	.045
Intercept	10508.449	1	10508.449	29.290	<.001	.332
POGIL	43.839	1	43.839	.122	.728	.002
Pre-test	987.392	1	987.392	2.752	.102	.045
Error	21167.575	59	358.772			
Total	211692.000	62				
Corrected Total	22156.774	61				

a. R Squared = .045 (Adjusted R Squared = .012)

Table **8** shows that F (1, 59) = 0.122, with P = 0.728 and $n^2\rho = 0.002$ within the experimental groups at P < 0.05. The ANCOVA result revealed F=0.122 and p=.728 P > 0.05. This means that the null hypothesis HO_4, which says there is no significant difference in the mean performance of male and female students' taught geometry using POGIL is retained. Hence the alternative hypothesis (Hα) that there is significant difference in the mean performance of male and female students' taught geometry using POGIL is rejected. This result shows that the use of POGIL strategy in teaching geometry has no statistically significant difference between male and female students' performance of the experimental group.

5 Discussion

Based on the findings of the study, it was suggested that the teaching of Geometry can be made to be more concrete that could leads to better students' performance in concept(s) that have been tagged difficult areas in mathematics and mathematics as a whole, when the right strategies are employed. Obviously, POGIL has been find to be one of this effective approaches. The result in Table **1** shows that the metacognitive skills mean scores of the experimental post-test group gains a mean difference of 14.32 in favour of POGIL. This result are in line with the findings of (Triani et al., 2025) which found that students taught using POGIL had significantly higher metacognitive skills and abilities compared to those in the lecture method group at $P \leq 0.05$. Similarly, the study is in line with findings by (Jeong et al., 2020) and that of (Shadburn et al., 2018) on POGIL-based geometry instruction showed significant improvements in their metacognitive skills. Furthermore, the study is in line with the findings of (Belay, et al., 2026) that students who participated in POGIL had significantly higher scores on their geometry pre and post-tests than those who did not.

Similarly, the result is in concordance with findings by Gabel and Sherwood (2015) and (Fediuk et al., 2018) that students who engaged in POGIL activities demonstrated increased metacognitive awareness and self-regulation. Similarly, the result in table 3 revealed that the post-test performance means of the experimental group 55.29 is greater than those of the control group 39.12. Hence, the result shows that students taught Geometry using POGIL gains 16.17 higher performance mean scores than those taught using the conventional method. The result in this study agrees with the findings of (Belay, et al., 2026) which revealed that students in the POGIL group achieved significantly higher scores in geometry assessments, indicating improved understanding and application of geometric concepts. The result reveals that the metacognitive skills post-test mean of male of the experimental group were 55.33 and 59.12, respectively. This result further shows that the male students gains 13.20 metacognitive skills from the pre-test score 42.13 while the female student gains 10.31 from pre-test score of 48.81. From this result it is obvious that the use of POGIL strategy in teaching geometry has no gender bias on students' metacognitive skills. In addition, the result reveals that the post-test mean performance of male and female students of the experimental were M=55.47 and M=55.13 and SD=18.95 and SD=19.46, respectively. The results of the ANCOVA in Table **6** and Table **8**, revealed that p>.05. The result further revealed that the employment of pedagogical strategy (POGIL) on metacognitive skills and performance of students in geometry is gender friendly. This result is in concordance with finding as those (e.g., Bitrus et al., 2020; Johnson, 2000 & Fierros, 1999) show no significant differences exist in the achievement between boys and girls. Moreover, students who participated in POGIL had significantly higher scores in metacognitive awareness than those who did not.

6 Conclusion

Based on the findings of the study, it was concluded that teaching Geometry using POGIL have positive effect on the metacognitive skills and performance of students compared with those students taught same concept using the conventional method. Moreover, the findings revealed insights into the effectiveness of POGIL in enhancing metacognitive skills and performance in Geometry among secondary school students. The implications of the results is for teaching practices, Curriculum developers, and Educational policy makers to focus more in promoting innovative and interactive pedagogical approaches that are relatively student Centre in the mathematics education programs.

Limitations

1. Quasi-experimental design: The study lacks random assignment, introducing potential selection bias. Differences between groups may reflect pre-existing differences rather than treatment effects.
2. Non-equivalent control group: The control group (n = 69) and experimental group (n = 62) were not matched on key variables (e.g., prior achievement, socioeconomic status, teacher quality).
3. Purposive sampling: Two schools were selected purposively based on "accessibility and availability of resources," limiting generalizability to other schools in Kaduna State or Nigeria.
4. Small sample size for subgroup analysis: The gender analysis within the experimental group (30 males, 32 females) may be underpowered to detect small-to-moderate effects.
5. No follow-up assessment: The study measures immediate posttest outcomes only; it does not assess retention or transfer over time.

Recommendations

The following recommendations are put forward by the researcher

1. Teachers are encouraged to use pedagogical strategies such as POGIL in the teaching of Geometric concept as to improve students' performance in Mathematics.

2. The use of POGIL in teaching to Geometry and mathematics at large should be encouraged in developing and increasing student's metacognitive skills.

3. It was suggested that more studies should be conducted on the effect of teachers' pedagogical approaches on the metacognitive skill and performance of student in Geometry in Zaria educational zone of Kaduna state.

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