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Cooperative Learning Strategy: A Paradigm to Academic Performance of Senior Secondary Schools Mathematics

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ABSTRACT

This study investigated the effects of a cooperative learning strategy on the mathematics performance of Senior Secondary School Year Two (SSS 2) students in simultaneous equations in Lagos State, Nigeria. Using a quasi-experimental pretest and posttest non-equivalent control group design, a sample of 118 students (66 males and 52 females) drawn from two public secondary schools in Badagry Local Government Area was purposefully assigned at the school level to either a cooperative learning treatment group ($n = 48$) or a conventional instruction control group ($n = 70$). The Mathematics Achievement Test (MAT), comprising 20 multiple-choice and five essay items on simultaneous equations, was administered as both pretest and posttest. Instrument validity was established through face and content validation, whilst reliability was confirmed using the Kuder–Richardson Formula 21 (KR-21), yielding a coefficient of 0.74. Analysis of Covariance (ANCOVA), with pretest scores as the covariate, revealed a statistically significant difference in posttest performance between the cooperative learning and conventional groups [$F(1, 107) = 31.76$, $p < .05$, partial $\eta^2 = .23$]. No statistically significant main effect of gender [$F(1, 107) = 1.46$, $p = .23$, partial $\eta^2 = .01$] nor a significant interaction effect between teaching strategy and gender [$F(1, 107) = 0.03$, $p = .88$, partial $\eta^2 = .00$] was observed. The findings indicate that cooperative learning substantially improves mathematics achievement relative to conventional instruction, irrespective of student gender. It is recommended that secondary school mathematics teachers adopt cooperative learning strategies particularly the Student Teams–Achievement Divisions (STAD) model as a core pedagogical approach.

Keyword: Performance, Route, Mathematics, Cooperative learning, Algebra.

INTRODUCTION

Mathematics occupies a foundational role in science, technology, and economic development. At the national level, the Nigerian educational system treats mathematics as a compulsory subject from primary through senior secondary school, acknowledging its centrality to technological advancement and scientific literacy (Niyi et al., 2024; Osakuade, 2024). Despite this institutional emphasis, persistent underperformance in the subject particularly at the senior secondary school level continues to undermine national development objectives. Results from the West African Senior School Certificate Examination (WASSCE) consistently indicate that large proportions of candidates fail to attain credit-level passes in mathematics (Chukwurah, 2024), with simultaneous equations frequently cited among the most problematic topics. Contributing factors identified in the literature include inadequate instructional resources, teacher-centred pedagogies that limit student engagement, and insufficient subject-matter preparation amongst teachers (Shulman, 1987; Inekwe & Zakariyya, 2022; Aden & Ajibola, 2024).

Prevailing instructional approaches in Nigerian secondary school classrooms are predominantly teacher-centred, characterised by extended didactic lectures, restricted student–student interaction, and limited opportunities for collaborative sense-making (Ajaja & Eravwoke, 2025; Boadu et al., 2024). Such approaches position learners as passive recipients of mathematical knowledge rather than active constructors of understanding. Student-centred alternatives, particularly cooperative learning, have attracted growing empirical attention globally. Cooperative learning structures learners into small, interdependent groups tasked with shared academic goals; research consistently links this approach to improved achievement, enhanced peer relationships, and greater motivation across subject domains (Johnson et al., 2020; Slavin, 2023; Roseth et al., 2022). A recent meta-analysis by Al-Mutairi et al. (2025) reported a pooled effect size of d = 0.71 for cooperative learning on mathematics achievement, whilst Liu et al. (2025) found that collaborative strategies yielded the greatest gains when tasks were cognitively demanding and facilitated by targeted teacher intervention. However, evidence from the Nigerian context particularly at the senior secondary school level and with content-specific interventions targeting simultaneous equations remains sparse.

This study therefore examined the differential effects of cooperative learning and conventional instruction on the mathematics performance of SSS 2 students in simultaneous equations in Badagry local government area of Lagos State. Specifically, the study addressed the potential moderating role of student gender, given the conflicting findings in the literature regarding gender differences in mathematics achievement (Kaiser & Zhu, 2022; Olatoye & Adekoya, 2019; Ginga et al., 2019). The contribution of the present investigation lies in its context-specific empirical evidence grounded in the Nigerian public school system and in its direct focus on simultaneous equations, a topic of known difficulty at this level.

Research Questions

Three research questions and their corresponding null hypotheses guided the study:

(i) What is the mean difference in the performance of students taught through cooperative learning and those taught through conventional instruction?

(ii) What is the main effect of student gender on performance?

(iii) What is the interaction effect of teaching strategy and gender on student performance?

The theoretical basis for this study draws on two complementary frameworks: Vygotsky's (1978) sociocultural theory and constructivist learning theory. Vygotsky's concept of the Zone of Proximal Development (ZPD), the cognitive space between what a learner can accomplish independently and what they can achieve under guided peer or expert support—is especially pertinent in heterogeneous Nigerian classrooms, where variation in student ability within single classrooms is marked (Daramola et al., 2024). Cooperative learning operationalises the ZPD by structuring peer explanation, scaffolded dialogue, and shared problem-solving as routine features of instruction. Constructivist theory complements this perspective by emphasising that mathematical knowledge is actively constructed through social interaction and reflection rather than passively received (Gray, 2011; Slavin, 2014). Together, these frameworks predict that structured cooperative interaction should produce deeper conceptual understanding and stronger achievement outcomes than conventional transmission-based teaching.

Cooperative Learning and Mathematics Achievement

A substantial body of empirical research supports the effectiveness of cooperative learning for improving mathematics achievement. Slavin (2023) synthesised decades of evidence concluding that well-implemented cooperative learning consistently outperforms conventional instruction, with effects particularly robust when individual accountability and group goals are explicit features of the design. The meta-analysis by Al-Mutairi et al. (2025) confirmed a moderate-to-large pooled effect size (d = 0.71) across mathematics outcomes, whilst Liu et al. (2025) and Roka (2024) demonstrated that gains are most pronounced when tasks require higher-order reasoning, a characteristic of simultaneous equations. At the secondary school level in sub-Saharan Africa, Boadu et al. (2024) found cooperative strategies superior to conventional methods in Ghanaian secondary schools, and Ibrahim and Adetutu (2021) documented significant achievement advantages for cooperative learning over conventional instruction in Nigerian secondary school mathematics. Inekwe and Zakariyya (2022) similarly reported positive effects in Kano State, Nigeria. These findings from proximate educational contexts strengthen the theoretical expectation that cooperative learning would benefit Nigerian SSS 2 students studying simultaneous equations.

Gender and Mathematics Achievement

The relationship between gender and mathematics achievement has generated a substantial but inconsistent body of evidence. Some studies report advantages for male students (Bilesanmi-Awoderu, 2022; Mutai, 2016; Oluyemo et al., 2020), whilst others document no significant gender difference (Olatoye & Adekoya, 2019; Musimenta et al., 2020; Ginga et al., 2019). Kaiser and Zhu (2022) concluded, in a review of international evidence that gender gaps are narrowing globally but remain context dependent. In the cooperative learning literature specifically, Chiakwelu and Okigbo (2020) found no significant interaction between gender and cooperative learning strategy on mathematics achievement in Nigerian secondary schools a finding that guided the formulation of the third hypothesis in the present study.

Simultaneous Equations

In Nigeria's secondary school mathematics curriculum, as well as in many other educational institutions across the world, simultaneous equations play a crucial and persistent role. They are especially rich for instructional research because they are a topic that lies at the nexus of logical reasoning, algebraic reasoning, and practical problem solving. Simultaneous equations were chosen as the research instrument's content area for this study, which looks at the caliber of instructor discourse and student participation in cooperative learning environments. The topic's conceptual richness, its place in the Senior Secondary School Mathematics Curriculum as prescribed by the Nigerian Educational Research and Development Council (NERDC), and how well it fits the types of verbal interaction and collaborative reasoning that the study aims to explore all played a role in this decision.

When two or more equations have similar variables and are concurrently satisfied by the same set of values, they are referred to as simultaneous equations. Although quadratic-linear systems are also covered at this level, systems of two linear equations in two unknowns are the main focus in the senior secondary school setting. The topic is a great way to assess the caliber and depth of mathematical discourse in the classroom since it requires students to incorporate past knowledge of algebraic manipulation, substitution, and graphical representation. The nature of simultaneous equations, the main types encountered at the senior secondary level, the established techniques of solution, and the educational and research rationale for their selection as the instrument topic for this study are all thoroughly explained in this section.

The Nature and Conceptual Foundation of Simultaneous Equations

Fundamentally, a simultaneous equation issue gives the learner two or more relationships between the same variables, each of which limits the range of potential values for those variables. Since there are endless pairs of values that fulfill a single linear equation in two unknowns, x and y, it has an unlimited number of solutions. The solution set is further limited when a second equation involving the same two unknowns is given, and typically a unique pair of values that simultaneously satisfy both equations emerges. The name comes from the point at which the two relationships are simultaneously true, which is represented by this unique solution. Conceptually, simultaneous equations are among the first examples of a system a mathematical structure in which individual elements are interrelated and must be taken into consideration collectively rather than separately that secondary school student's meet. Simultaneous equations are regarded as a gateway issue in the secondary school curriculum because of this systemic thinking, which is fundamental to higher mathematics. Adolphus (2011) pointed out that success in subjects like coordinate geometry, matrices, and linear programming requires the ability to solve systems of equations, highlighting the significance of students gaining true conceptual understanding at this stage rather than just memorizing procedures.

However, the following research questions were generated by the study: (i) What is the mean difference in students' performance in cooperative learning 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 H01: There is no significant difference between the performance of students in cooperative learning classroom and those in the conventional classroom. H02: There is no significant effect of students' gender on performance in cooperative learning classroom and those in the conventional classroom.

H03: There is no significant interaction effect of the teaching strategies and students' gender on performance of students in cooperative learning classroom and those in the conventional classroom.

METHODS

A quasi-experimental pretest and posttest non-equivalent control group design was employed. Because intact school classes were used and full random assignment of individual participants was not feasible, this design appropriately controlled for pre-existing group differences by including pretest scores as a covariate in the inferential analyses (Creswell & Creswell, 2018). There were two senior secondary schools used in the study, one of which was designated as the treatment group and the other as the control group. The layout of the research design is shown below:

$$O_1 \quad X_1 \quad O_2 \quad (E)$$

$$O_3 \quad X_2 \quad O_4 \quad (C)$$

Figure 1: 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 (cooperative learning);

X_2: represents the treatment for the control group (Conventional method approach);

C: represents the control group;

E: represents the experimental group;

In this quasi-experiment, the pretest was utilized for the first observations (O1 and O3), the strategy (X1 and X2) in the treatment and control groups, and the posttest for the final observations (O2 and O4). Two groups underwent the intervention procedure in this investigation. In order to improve the students' comprehension of the concepts, a facilitator led the class in a cooperative learning approach while teaching the treatment group (E) simultaneous equations in mathematics. The control group (C) was taught the same topic using the conventional method.

Study Context, Population, Sample and Sampling Technique

The target population comprised all public senior secondary school II (SSS 2) students in Lagos State, Nigeria. The accessible population was restricted to SSS 2 students in Badagry Local Government Area (LGA), Education District V, Agboju, in Lagos State. Two intact classes from two public secondary schools in this district were selected. Badagry Local government area was selected using convenience sampling based on researcher proximity, whilst the two schools were subsequently selected by simple random sampling from among eligible institutions in the local government area. SSS 2 was targeted because simultaneous equations appear in the SSS 2 mathematics scheme of work as prescribed by the National curriculum.

The final sample comprised 118 students: 66 males and 52 females. One school was designated the treatment group ($n = 48$) and the other the control group ($n = 70$). The two mathematics teachers serving as facilitators held comparable academic qualifications (Bsc (Ed) in Mathematics Education) and 10 years of teaching experience, thereby minimising teacher-effect confounding.

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Instructional Procedure

Both groups received instruction on simultaneous equations over five weeks. In Week 1, a pretest was administered to both groups. During Week 2 to week 4, instruction was delivered: Week 2 covered the substitution method; Week 3, the elimination method; and Week 4, word problems leading to simultaneous equations. In Week 5, the posttest was administered.

The treatment group was taught using the cooperative learning strategy, organised around the Student Teams–Achievement Divisions (STAD) model, in which a trained facilitator (teacher) guided structured small group activities. The control group received instruction through the conventional whole-class teacher-centred approach, also delivered by a trained facilitator. Both facilitators underwent two weeks of training prior to the intervention to ensure fidelity to their respective instructional approaches.

Instrumentation

The instrument used was the Mathematics Achievement Test (MAT), which comprised 20 multiple-choice items and five essay questions, all based on the simultaneous equations content taught during the intervention. The MAT was administered as both pretest and posttest, with the intervention interposed between the two administrations. Face and content validity were established through expert review involving experienced mathematics education colleagues and a research methodology specialist, who examined item relevance, coverage of the curriculum, and structural adequacy. Reliability was assessed using the Kuder–Richardson Formula 21 (KR-21), yielding a coefficient of 0.74, which exceeds the conventional threshold of 0.70 for internally consistent instruments (Fraenkel et al., 2019).

Data collection

The volunteer teacher from each school served as a facilitator after two weeks of training. The researchers gave the pre-test to the treatment and control groups at the selected school before to the intervention in order to gauge their involvement in the five-week activity. In the first week, the pretest was given; in the second week, the first lesson was delivered; in the third week, the second lesson was given; in the fourth week, the third lesson was given; and in the fifth week, the posttest was given.

Data analysis

As part of a methodical examination of the data, the parametric assumptions were evaluated first, then the inferential statistics. Levene's test of homogeneity of variance ($F = 2.58$; $p>0.05$) showed no significant difference between the two groups; the Shapiro-Wilk test of normality showed that the data in both the treatment group ($N = 48$) = 0.90, $p > 0.05$, and the control group ($N = 70$) = 0.94, $p > 0.05$, were normally distributed; descriptive statistics (bar chart, percentage, frequency count, averages, and standard deviation) were used to test the hypotheses at the significance level of 0.05.

After these assumptions were met, the students' achievement scores in both groups were examined using the Analysis of Covariance (ANCOVA) statistics at the 0.05 significance level for hypotheses, while descriptive statistics (percentage count and bar chart) were employed for the study's research questions.

The accomplishment scores were the dependent variable for the ANCOVA, the teaching tactics were the fixed factor, and the pretest results were the covariate. The researchers had to use analysis of covariance to partially ascertain the influence of any initial difference between the treatment and control groups because the students were not randomly assigned to groups. This could have skewed the data's conclusions. The collected data was analyzed using IBM-SPSS version 23.

RESULTS

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

Table 1: Descriptive Statistics of Group Performance in the Pretest and Posttest

Index	Statistics in the Pretest		Statistics in the Posttest	
	Treatment	Control	Treatment	Control
Mean	14.00	9.03	25.00	13.79
SD	7.06	3.02	9.44	4.53

Table 1 presents the descriptive statistics for both groups. The treatment group demonstrated a mean gain of 11.00 score points between pretest (M = 14.00, SD = 7.06) and posttest (M = 25.00, SD = 9.44), whilst the control group showed a substantially smaller mean gain of 4.76 score points (pretest: M = 9.03, SD = 3.02; posttest: M = 13.79, SD = 4.53). These descriptive patterns suggest that the cooperative learning intervention was associated with greater performance improvement than conventional instruction. The inferential test of this difference is reported under Hypothesis one.

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

Table 2 Descriptive Statistics of Student Performance by Gender Across Pretest and Posttest

Index	Statistics in the Pretest		Statistics in the Posttest	
	Male	Female	Male	Female
Mean	10.06	12.26	17.09	19.89
SD	4.42	6.62	7.48	10.17

Table 2 presents descriptive statistics by gender. Both male and female students recorded improvements from pretest to posttest, with male students gaining a mean of 7.03 score points and female students gaining 7.63 score points. The similarity of these gains suggests that both groups benefited comparably from instruction, irrespective of teaching strategy. The inferential test of the gender main effect is reported under Hypothesis one.

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

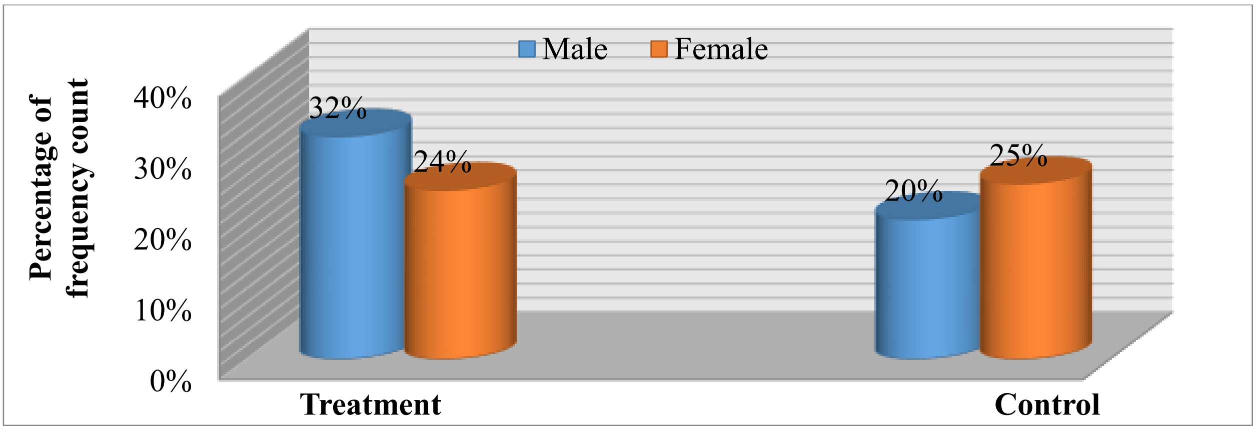

Figure 2: Interaction effect of teaching strategies and gender

In the treatment group, 32 male students had a frequency count of 32% whereas 33 female students had a frequency count of 20%, while in the control group, 16 male students had a frequency count of 20% whereas 37 female students had a frequency count of 25%. Notably, neither teaching strategies nor gender had an interaction effect with the performance of students in the cooperative learning 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: there is no significant difference between the performance of students in cooperative learning classroom and those in the conventional classroom.

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

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7781.03[a]	10	778.10	59.23	0.00	0.85
Intercept	169.43	1	169.43	12.90	0.00	0.11
Pretest	737.97	1	737.97	56.17	0.00	0.34
Group	417.20	1	417.20	31.76	0.00	0.23
Error	1405.73	107	13.14			
Total	48909.00	118				
Corrected Total	9186.75	117				
a. R Squared = .847 (Adjusted R Squared = .833)						

Table 3 presents the ANCOVA results. After controlling for pretest differences, there was a statistically significant effect of teaching strategy on posttest performance, $F(1, 107) = 31.76$, $p < .001$, partial $\eta^2 = .23$. This represents a large effect size by conventional benchmarks (Cohen, 1988), indicating that 23% of the variance in posttest scores was attributable to the instructional strategy used. The pretest covariate was also statistically significant, $F(1, 107) = 56.17$, $p < .001$, partial $\eta^2 = .34$, confirming that it accounted for meaningful variance in posttest scores and that its inclusion in the model was appropriate. H01 is therefore rejected: students in the cooperative learning group performed significantly better than those in the conventional instruction group after controlling for prior achievement.

Research Hypothesis Two: There is no significant effect of students' gender on performance in cooperative learning classroom and those in the conventional classroom.

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

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7781.03[a]	10	778.10	59.23	0.00	0.85
Gender	19.23	1	19.23	1.46	0.23	0.01
Error	1405.73	107	13.14			
Total	48909.00	118				
Corrected Total	9186.75	117				
a. R Squared = .847 (Adjusted R Squared = .833)						

The ANCOVA revealed no statistically significant main effect of gender on posttest performance, $F(1, 107) = 1.46$, $p = .23$, partial $\eta^2 = .01$. The effect size is negligible (< .01), indicating that gender accounted for less than 1% of the variance in posttest scores. H02 is therefore retained: gender did not significantly differentiate student performance under either instructional condition.

Research Hypothesis Three: There is no significant interaction effect of the teaching strategies and students' gender on performance of students in cooperative learning classroom and those in the conventional classroom.

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

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	7781.03[a]	10	778.10	59.23	0.00	0.85
Group * Gender	0.32	1	0.32	0.03	0.88	0.00
Error	1405.73	107	13.14			
Total	48909.00	118				
Corrected Total	9186.75	117				
a. R Squared = .847 (Adjusted R Squared = .833)						

No significant interaction effect was found between teaching strategy and gender, $F(1, 107) = 0.03$, $p = .88$, partial $\eta^2 = .00$. The negligible effect size confirms that the differential effect of cooperative learning over conventional instruction was consistent across male and female students. H03 is therefore not rejected: the benefit of cooperative learning relative to conventional instruction did not vary as a function of student gender.

DISCUSSION OF RESULTS

The primary finding of this study that students taught through cooperative learning performed significantly better on a posttest of simultaneous equations than those taught through conventional instruction ($F(1, 107) = 31.76$, $p < .001$, partial $\eta^2 = .23$) is consistent with a broad and growing body of evidence supporting the effectiveness of cooperative learning in mathematics education. The magnitude of the effect (23% of variance explained) aligns with the moderate-to-large effect sizes reported by Al-Mutairi et al. (2025) and Slavin (2023) and exceeds the small-to-moderate effects typically attributed to isolated instructional innovations in Nigerian secondary schools. Ibrahim and Adetutu (2021), who documented significant achievement advantages for cooperative learning over conventional instruction in Ekiti State, reported a comparable pattern, lending ecological validity to the current findings within the Nigerian educational context.

The mechanism underlying these performance gains is theoretically grounded in Vygotskian scaffolding and constructivist knowledge building. In the cooperative learning classrooms in this study, structured group interaction enabled students to articulate their thinking, receive corrective peer feedback, and collaboratively apply substitution, elimination, and word problem strategies to simultaneous equations. This mode of active engagement aligns with the argument advanced by Boadu et al. (2024) and Daramola et al. (2024) that passive, teacher-directed classrooms deprive students of the cognitive activation necessary for deep mathematical understanding. The mean gain of 11.00 score points in the treatment group versus 4.76 score points in the control group both observed in five weeks intervention suggests that even relatively brief cooperative learning programmes can produce meaningful achievement differences, provided the instructional design incorporates clear group goals and individual accountability (Johnson et al., 2020).

The absence of a significant gender main effect on posttest performance ($F(1, 107) = 1.46$, $p = .23$, partial $\eta^2 = .01$) extends findings from Musimenta et al. (2020) and Ginga et al. (2019), who similarly reported negligible gender differences in mathematics achievement under cooperative learning conditions. This outcome challenges the persistent narrative evident in studies by Mutai (2016) and Oluyemo et al. (2020) that male students are inherently advantaged in mathematics, suggesting instead that gender disparities in this domain may be pedagogically mediated. When the instructional environment is structured to promote equitable participation and shared accountability, as in the STAD model used here, gender ceases to be a significant determinant of performance. The non-significant interaction effect between teaching strategy and gender ($F(1, 107) = 0.03$, $p = .88$, partial $\eta^2 = .00$) reinforces this conclusion: cooperative learning yielded comparable benefits for both male and female students, a finding consistent with Chiakwelu and Okigbo (2020).

These findings carry practical implications at various levels. For classroom practitioners, the study provides direct evidence that restructuring instruction around cooperative group activities specifically the STAD model can substantially improve performance in simultaneous equations, a topic that many Nigerian students find persistently challenging. For school administrators and curriculum developers, the results argue for systematic professional development in cooperative learning implementation, with particular attention to group composition, task design, and facilitation skills. At the policy level, the findings support a re-orientation of secondary school mathematics pedagogy in Lagos State and Nigeria more broadly, away from whole-class, teacher-fronted delivery and towards student-centred, collaborative models that leverage the social dimensions of mathematical learning.

The study also diverges from Reyes (2019), who found no significant difference between cooperative learning and conventional instruction in teaching discrete probability distributions. This discrepancy may reflect content-domain specificity: the procedural-conceptual blend required in simultaneous equations and the availability of multiple solution strategies amenable to peer discussion may render this topic particularly suited to cooperative learning, more so than probability concepts requiring more abstract statistical reasoning.

CONCLUSION

This study demonstrated that cooperative learning significantly improved the mathematics achievement of senior secondary school students studying simultaneous equations in Lagos State, Nigeria, relative to conventional whole-class instruction, whilst producing no differential benefit based on student gender. These findings affirm the theoretical predictions of Vygotskian and constructivist frameworks and contribute context-specific evidence to the predominantly global literature on cooperative learning in mathematics education.

The study is subject to several limitations. First, the sample was drawn from a single LGA in Lagos State, limiting the generalisability of the findings to other regions, school types, or demographic contexts. Second, the relatively small sample ($n = 118$) and the allocation imbalance between treatment ($n = 48$) and control ($n = 70$) groups may affect the precision of effect size estimates. Third, the use of convenience sampling at the district level and purposive sampling at the teacher level introduces selection biases that random sampling would have mitigated. Fourth, the five-week duration of the intervention precludes conclusions about the long-term retention of cooperative learning gains. Fifth, the study relied on a single instrument (the MAT) to measure achievement; triangulation with qualitative observation data would enrich interpretation.

Future research should address these limitations by employing larger, multi-site samples with stratified random sampling across diverse Nigerian states and school types, and by extending the intervention period to permit follow-up retention testing. Researchers should also examine fidelity of implementation as a moderating variable, investigate the effects of different cooperative learning models (e.g., Jigsaw, Think Pair Share) on simultaneous equations performance, and explore the role of teacher professional development in sustaining cooperative learning practices beyond experimental conditions.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are advanced:

1. Secondary school mathematics teachers should incorporate the STAD cooperative learning model as a primary instructional strategy for algebraic topics, including simultaneous equations, given the evidence that it significantly outperforms conventional instruction for both male and female students.

2. State ministries of education and school administrators should invest in structured professional development programmes that equip mathematics teachers with the skills to design, facilitate, and assess cooperative learning activities effectively.

3. Teacher training institutions should integrate cooperative learning pedagogy including group design principles, accountability structures, and formative assessment strategies into pre-service mathematics education curricula.

Ethical Considerations

Ethical approval was obtained from the relevant school authorities prior to data collection. School principals and administrators granted written permission for the study to proceed. Informed consent was obtained from all participants via a written consent form that clearly described the study's objectives, the voluntary nature of participation, and the confidentiality of responses. Participants were free to withdraw from the study at any time without penalty. No participant experienced physical or psychological harm during the research process. All participant data were anonymised during transcription and analysis using pseudonyms.

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