

## Advancing Inclusive Mathematics Education through Logic-Based Instruction: Gender Perspectives on Upper Basic Students' Achievement in Directed Numbers in Egbeda, Oyo State

Raheem, Tunde Rasheed<sup>1</sup> and Sam-Kayode, Christianah Olajumoke<sup>2</sup>

<sup>1</sup>Department of Computer Science (Mathematics Unit), Faculty of Natural and Applied Sciences;

<sup>2</sup>Department of Science and Technology Education, Faculty of Education.

<sup>1,2</sup>Lead City University, Ibadan, Oyo State, Nigeria

### Abstract

Inclusive and equitable Mathematics education is essential for sustainable development, particularly at the upper basic level where foundational concepts shape future learning pathways. Directed numbers introduce learners to integers, additive inverse relationships, and inequalities, yet persistent learning difficulties and concerns about gender disparities continue to affect students' achievement. This study investigated the main and interaction effects of gender and a logic-based teaching strategy on upper basic students' achievement in directed numbers in Egbeda Local Government Area, Oyo State. Two hypotheses were formulated and tested at the 0.05 level of significance. A quasi-experimental pre-test, post-test control group design was adopted. Using a multistage sampling procedure, two public junior secondary schools were selected, yielding a sample of 49 JSS II students (23 males and 26 females). Data were collected using the Integer Operations Achievement Test (IOAT) ( $KR-20 = 0.76$ ) and analyzed using Analysis of Covariance (ANCOVA). Results revealed no significant main effect of gender ( $F_{(1, 46)} = 0.192, p > 0.05$ , partial  $\eta^2 = 0.004$ ) and no significant interaction effect of gender and logic-based teaching strategy ( $F_{(3, 44)} = 0.926, p > 0.05$ , partial  $\eta^2 = 0.059$ ) on upper basic students' achievement in directed numbers. However, descriptive results indicated that the logic-based strategy reduced observable gender performance gaps when compared with the traditional teaching approach, suggesting a more

balanced learning environment for both male and female students. In contrast, the traditional strategy displayed wider gender disparities in achievement. Although the interaction effects did not reach statistical significance, the study highlights the potential of logic-based instructional approaches to promote inclusivity and equity in Mathematics learning. It concludes that fostering inclusive futures in education requires sustained exploration of learner-centered and cognitively supportive strategies capable of narrowing gender gaps and strengthening conceptual understanding in foundational Mathematics topics. It is recommended that Mathematics teachers should integrate logic-based and learner-centered strategies alongside existing methods to strengthen conceptual understanding and promote equity.

*Keywords:* Inclusive Mathematics, Academic Achievement, Directed Numbers, Gender, Logic Based Teaching Strategy

## **Introduction**

Inclusive and equitable quality education remains central to sustainable development, particularly within science and Mathematics classrooms where foundational concepts shape learners' future participation in society (Jangde & Ahmad, 2025). Mathematics is a cornerstone of the Nigerian educational system and a key driver of such inclusive and equitable education. At the upper basic level, Mathematics instruction plays a critical role in shaping learners' cognitive development, logical reasoning, and readiness for advanced scientific and technological learning (Ikyanyi et al., 2023). Among these foundational concepts is Directed Numbers, which serves

as the formal introduction to integers and their operations. Through directed numbers, learners are expected to understand positive and negative values, the additive inverse, and comparisons using inequality symbols; skills that are fundamental to proficiency in broader integer operations. Despite the importance of this topic, many upper basic school students continue to struggle with persistent misconceptions that impede accurate computation and meaningful problem-solving (Gyampoh et al., 2020; Kwakye et al., 2022).

Research consistently shows that students demonstrate a wide range of misconceptions in learning integer operations. Common

errors include adding and subtracting signed numbers incorrectly, misapplying multiplication and division rules, and making persistent mistakes when converting verbal statements into mathematical expressions (Harun et al., 2024; Rosyidah et al., 2021). For instance, in addition of integers, learners often ignore the rule of combining unlike signs, producing incorrect answers such as  $3 + (-3) = 6$  or  $(-40) + 10 = -50$ . Similarly, in subtraction tasks such as “subtract 41 from  $-57$ ,” students frequently reverse the operation or misinterpret the phrase, giving responses like  $41 - 57$  instead of  $-57 - 41 = -98$ . These misconceptions become more pronounced when dealing with larger or smaller numbers or when transforming word problems into symbolic form (Harun et al., 2024).

The same problem is evident in multiplication and division. Many students forget or confuse sign rules, solving  $(-5) \times 6$  or  $16 \times (-4)$  as positive values, or mishandling like signs by concluding that  $(-8) \times (-5) = -40$  instead of 40. In division, students often calculate the correct numerical value but assign the wrong sign, for example solving  $45 \div (-9)$  as 5 instead of  $-5$ . These errors are strongly linked to procedural gaps,

rule confusion, and difficulty with negative signs (Harun et al., 2024).

Another critical gap relates to the misinterpretation of inequality symbols. A study involving pre-service teachers revealed that less than half correctly placed appropriate symbols between integers such as  $-12$  and  $8$ . Error rates increased when participants attempted to supply integers for inequalities such as  $y < -5$  and  $-10 < k$ , with many listings incorrect positive or negative values. These misconceptions were traced to early instructional practices that encouraged mechanical interpretation rather than conceptual understanding (Toxtle-Colotl et al., 2025).

A further gap concerns difficulties with additive inverse operations, where learners fail to transfer knowledge correctly when solving algebraic equations. For example, in the equation  $-x + 4 = 7$ , many students incorrectly conclude that  $x = 3$  instead of the correct solution  $x = -3$ . Similar errors occur when inequalities involve inverse operations, such as  $-x > -3$  and  $-x > 3$ , where students often fail to reverse the inequality sign appropriately. These challenges reflect confusion in handling inverse relationships

involving negative integers (Raheem et al., 2025).

Altogether, these gaps reveal deep-rooted challenges in students' conceptual understanding of integer operations. Misconceptions in addition, subtraction, multiplication, and division of signed numbers, alongside persistent difficulties with additive inverse and inequality symbols, underscore the urgent need for instructional approaches that prioritize conceptual clarity over procedural memorization.

Traditional methods of teaching, often characterized by rote memorization and repetitive drills, have not sufficiently addressed these challenges. Students may memorize rules for integer operations without developing the logical reasoning needed to apply them flexibly in new contexts. As a result, errors persist and learners struggle to transfer knowledge to unfamiliar or word-based problems. This limitation highlights the need for instructional strategies that promote logical reasoning and structured problem-solving (Raheem et al., 2025).

Another important dimension in Mathematics achievement is gender disparity. Research presents mixed findings on whether male or female students perform better in Mathematics. While some studies suggest that males often perform better in problem-solving tasks, others report that females perform equally well when supported by appropriate instructional strategies (Cahyadi et al., 2023; Norhaslina et al., 2025). In Nigeria, cultural expectations, classroom interactions, and learner confidence further influence how gender differences manifest in Mathematics learning outcomes.

Addressing these challenges requires instructional approaches that are both effective and inclusive. Inclusive Mathematics instruction accommodates diverse learning needs, backgrounds, and cognitive strengths. In this regard, logic-based teaching strategies provide a promising framework. Drawing on logical reasoning and coding principles particularly the use of truth tables and structured logical patterns; this strategy presents integer concepts in a systematic and visual manner. By mapping possible outcomes of operations involving

directed numbers, the approach reduces reliance on rote memorization, strengthens conceptual understanding, and supports learners who struggle with abstract numerical relationships (Phalguni et al., 2023; Raheem et al., 2025).

In Egbeda local government area of Oyo state, where upper basic school students are expected to acquire mastery of directed numbers as part of the national curriculum, persistent underachievement in Mathematics raises concerns for educators and policymakers alike. The integration of a logic-based teaching strategy into classroom instruction may provide a pathway to improving students' achievement in directed numbers, while also shedding light on how gender moderates its effectiveness.

Taken together, the evidence reveals three important gaps. First, despite the centrality of integer operations; misconceptions in additive inverse, sign rules, and inequality interpretation persist among learners in directed numbers, suggesting that current instructional methods are inadequate. Second, logic-based teaching strategy, though widely used in computing and engineering, remain underexplored in the

context of Nigerian secondary Mathematics classrooms, particularly in addressing students' difficulties with integers. Third, there is limited empirical evidence on how such strategies might interact with gender differences in Mathematics achievement. Addressing these gaps is crucial, not only for improving student outcomes in directed numbers but also for promoting gender equity in Mathematics education.

Anchored on this perspective, the present study examines the gender and logic-based teaching strategy effects on upper basic students' achievement in directed numbers in Egbeda Local Government Area, Oyo State, with attention to how the strategy compares with the traditional method and how factors such as gender may influence learning outcomes.

## **Literature Review**

Inclusive and equitable education has increasingly been positioned as a foundation for sustainable development, particularly in disciplines such as Mathematics where early conceptual understanding shapes later academic progression and societal participation (Jangde & Ahmad, 2025). In the

Nigerian context, Mathematics occupies a central place in the curriculum and serves as a gateway to science, technology, and innovation. At the upper basic level, instruction is expected to strengthen learners' logical reasoning, analytical thinking, and readiness for more advanced studies (Ikanyani et al., 2023). Within this framework, directed numbers represent a critical transition point, introducing students to integers, additive inverses, and inequality relationships that underpin algebraic reasoning. Despite its foundational importance, research continues to report persistent underachievement and widespread misconceptions in this topic (Gyampoh et al., 2020; Kwakye et al., 2022).

Empirical studies consistently document conceptual and procedural difficulties in students' understanding of integer operations. Learners frequently misinterpret the rules governing signed numbers, particularly in addition and subtraction, where unlike signs are often combined incorrectly (Harun et al., 2024; Rosyidah et al., 2021). Errors also arise in interpreting verbal statements and translating them into symbolic representations, indicating gaps in conceptual clarity rather than simple

computational weakness. Similar patterns are evident in multiplication and division of integers, where confusion about sign rules leads to systematic mistakes. Such misconceptions tend to intensify when tasks involve larger numbers, contextual word problems, or multiple-step reasoning (Harun et al., 2024).

Beyond computation, challenges extend to inequalities and inverse relationships. Research involving both students and pre-service teachers have shown limited understanding of comparing negative and positive integers and determining values that satisfy inequality statements (Toxtle-Colotl et al., 2025). Difficulties are further compounded when inverse operations are introduced in algebraic contexts, particularly where negative variables require careful manipulation and sign reversal (Raheem et al., 2025). These findings suggest that early exposure to integer operations often emphasizes procedural memorization without sufficiently developing conceptual reasoning, resulting in persistent misunderstandings.

Concerns about instructional effectiveness have therefore attracted considerable

scholarly attention. Traditional approaches, largely characterized by teacher-centered explanations and repetitive drills, have been criticized for reinforcing rule memorization at the expense of conceptual insight. Although such methods may improve short-term performance, they often fail to support flexible application of knowledge in unfamiliar situations. In response, researchers have advocated for instructional strategies that emphasize reasoning, structured representation, and active engagement (Raheem et al., 2025). Intervention studies indicate that concept-focused and scaffolded approaches can enhance mastery of integer operations and reduce recurring errors (Harun et al., 2024; Anggraeni et al., 2025). Similarly, the use of visual models and manipulatives has demonstrated positive effects on students' understanding of negative numbers and operational relationships (Lacaba, 2025).

One emerging approach is logic-based instruction, which draws on principles of structured reasoning, symbolic consistency, and pattern recognition. Grounded in logical frameworks such as truth tables and systematic coding structures, this strategy

organizes mathematical relationships in ways that make operational patterns explicit (Phalguni et al., 2023; Raheem et al., 2025). By presenting directed numbers through logical mappings of possible outcomes, learners are encouraged to analyze relationships rather than rely solely on memorized rules. Such structured representation has been associated with improved reasoning skills and clearer conceptual understanding, particularly in topics that require consistent application of sign conventions.

Another dimension frequently examined in Mathematics education research is gender disparity. Findings on gender differences in achievement remain inconclusive. Some studies suggest marginal male advantages in specific problem-solving contexts, while others report no significant differences when learners receive structured and supportive instruction (Cahyadi et al., 2023; Norhaslina et al., 2025). Additional research indicates that observed disparities may be influenced by sociocultural expectations, classroom interaction patterns, and learner confidence rather than inherent cognitive differences (Abdussakir et al., 2024). Notably, several

intervention studies have shown that when instructional methods are conceptually grounded and inclusive, gender-based performance gaps tend to diminish (Harun et al., 2024; Norhaslina et al., 2025; Raheem et al., 2025).

Despite growing interest in innovative pedagogies, limited empirical attention has been given to the application of logic-based teaching strategies within Nigerian upper basic Mathematics classrooms. Furthermore, few studies have systematically examined whether such strategies interact with gender in influencing achievement in directed numbers. Given persistent misconceptions in integer operations and ongoing concerns about equity in Mathematics learning, there is a clear need for context-specific research that evaluates both instructional effectiveness and gender-related outcomes.

The existing literature therefore highlights three interrelated issues: enduring conceptual difficulties in directed numbers, limitations of traditional instructional practices, and inconsistent evidence regarding gender differences in Mathematics achievement. Exploring logic-based instructional strategies within this context provides an opportunity to

address these gaps while contributing to broader efforts aimed at strengthening conceptual understanding and promoting inclusive, equitable learning environments in Mathematics education.

### **Statement of the Problem**

Directed Numbers introduce learners to the foundational principles of integers, including positive and negative values, the additive inverse, and inequality relationships. Despite their importance, evidence from classroom observations, internal assessments, and national examinations consistently shows that many upper basic school students experience substantial difficulties with this topic. Students often rely on memorized rules without understanding the underlying logic, leading to persistent misconceptions such as confusing the signs of numbers, misapplying addition and subtraction rules, and incorrectly interpreting inequalities. These challenges hinder their ability to solve problems accurately and limit their readiness for more advanced mathematical concepts that depend on integer reasoning. As classrooms become increasingly diverse, there is a growing need for inclusive instructional strategies that can address

varying learning styles and cognitive strengths. The logic-based teaching strategy, which employs truth tables, logical patterns, and coding structures, offers a systematic and transparent way of presenting integer relationships and may help reduce misconceptions by strengthening conceptual clarity. However, empirical evidence on the effectiveness of this approach in the Nigerian upper basic school context especially in relation to students' achievement in directed numbers is limited. Furthermore, it remains unclear whether gender differences influence how students respond to such a logic-driven instructional method. These gaps create uncertainty about the suitability and effectiveness of the logic-based teaching strategy for improving students' achievement in directed numbers. Therefore, there is a need for a study that examines its effect on student learning outcomes and explores whether gender interacts with this strategy to influence achievement.

### **Aim and Objectives of the Study**

The aim of this study is to investigate the Gender and Logic-Based Teaching Strategy Effects on Upper Basic Students' Achievement in Directed Numbers in Egbeda

Local Government Area, Oyo State, with a view to advancing inclusive Mathematics education. The objectives are to:

- i. determine the main effect of gender on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state; and
- ii. examine the interaction effect of gender and logic-based teaching strategy on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state.

### **Hypotheses**

The following null hypotheses will be tested at 0.05 level of significance:

**H<sub>01</sub>:** There will be no significant main effect of gender on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state.

**H<sub>02</sub>:** There will be no significant interaction effect of gender and logic-based teaching strategy on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state.

### **Methodology**

This study adopted a quasi-experimental research design, specifically the pre-test, post-test control group design. At the time of this study, the total population of JSS II students in the local government area was 4,301, made up of 2,135 males and 2,166 females (Oyo State Universal Basic Education Board, 2025). JSS II students were chosen because they had already been introduced to basic number operations in earlier classes and were at an appropriate stage for more advanced learning of integer operations. A two-stage multistage sampling procedure was employed. In the first stage, schools were stratified according to wards: Stratum 1 consisted of Wards 1 to 5, while Stratum 2 comprised Wards 6 to 11. In the second stage, one school was randomly selected from each stratum. By balloting, School A in Ward 1 was selected and assigned to the experimental group, while School B in Ward 6 was selected and assigned to the control group. Each school contributed one intact JSS II class, giving a total sample of 49 students. The experimental

group consisted of 30 students (14 males and 16 females) taught directed numbers using the logic-based teaching strategy, while the control group comprised 19 students (9 males and 10 females) taught the same content using the traditional teacher-centered method. Integer Operations Achievement Test (IOAT) and Directed Numbers Teaching Instructional Guides for both logic-based and traditional teaching strategies were used as research instruments for data collection and subjected to face and content validation, while Kuder-Richardson (KR-20) formula was applied to establish reliability of IOAT yielding 0.76 as an acceptable reliability coefficient for the study. Data collection lasted for eight weeks, the process adhered to the following time schedule: Week One: Training of research assistants; Week Two: Administration of pre-test; Week Three – Seven: Implementation of the treatment; and Week Eight: Administration of post-test. Analysis of Covariance (ANCOVA) was employed for data analysis to test the hypotheses at the 0.05 level of significance.

### Results: Test of Hypotheses

**H<sub>01</sub>:** There will be no significant main effect of gender on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state.

<b>Table 1: Tests of Between-Subjects Effects of Gender on Upper Basic Students' Achievement in Directed Numbers</b>							
Dependent Variable: Posttest							
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	
Corrected Model	540.606 <sup>a</sup>	2	270.303	23.578	0.000	0.506	
Intercept	40.498	1	40.498	3.533	0.067	0.071	
Pretest	538.299	1	538.299	46.955	0.000	0.505	
Gender	2.197	1	2.197	0.192	0.664	0.004	
Error	527.353	46	11.464				
Total	9611.000	49					
Corrected Total	1067.959	48					

a. R Squared = 0.506 (Adjusted R Squared = 0.485)

**Source:** Researcher's Fieldwork, 2026.

From Table 1: The Analysis of Covariance (ANCOVA) result on the main effect of gender on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state was;  $F_{(1; 46)} = 0.192$ ,  $p > 0.05$ ,  $\text{partial } \eta^2 = 0.004$ . The findings clearly demonstrate that the gender did not make a meaningful contribution to students' post-test performance. Therefore, there was no significant main effect of gender

on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state. Since  $p > 0.05$ , the difference in performance between male and female students was not statistically significant. Male and female students performed similarly when exposed to the instructional activities, suggesting that the concept of directed numbers did not favour one gender over the other in this study

<b>Table 2: Parameter Estimates of Gender on Upper Basic Students’ Achievement in Directed Numbers</b>							
Dependent Variable: Posttest							
Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	3.170	1.656	1.914	0.062	-.163	6.503	0.074
Pretest	0.898	0.131	6.852	0.000	0.634	1.161	0.505
[Gender=Female]	-0.424	0.969	-0.438	0.664	-2.375	1.527	0.004
[Gender=Male]	0.000 <sup>a</sup>	0.000	0.000	0.000	0.000	0.000	0.000

a. This parameter is set to zero because it is redundant.

**Source:** Researcher’s Fieldwork, 2026.

Table 2: The parameter estimates provide further insight into whether gender influenced students’ achievement in directed numbers after controlling for their pre-test scores. The results again show that gender did not have a meaningful effect.

The coefficient for females ( $B = -0.424$ ,  $p = 0.664$ ) indicates that, after adjusting for pre-test performance, female students scored slightly lower than male students on the post-test. However, this difference was not statistically significant, as the p-value is

much greater than the 0.05 threshold. The confidence interval ( $-2.375$  to  $1.527$ ) also crosses zero, confirming that the observed difference could have occurred by chance. The partial eta squared value of 0.004 shows that gender explained less than one percent of the variance in achievement, indicating no practical influence.

In contrast, the pre-test score had a strong and statistically significant effect on the post-test ( $B = 0.898$ ,  $p < 0.05$ ), meaning students who performed well initially were more likely to

achieve higher scores after the intervention. The intercept was not significant, showing no meaningful baseline difference after accounting for the covariate. Overall, the parameter estimates reinforce that gender did

not contribute significantly to students' achievement in directed numbers. Therefore, the null hypothesis stating that gender has no significant main effect is supported.

<b>Table 3: Estimated Marginal Means of Gender on Upper Basic Students' Achievement in Directed Numbers</b>				
Dependent Variable: Posttest				
Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Female	13.005 <sup>a</sup>	0.664	11.668	14.342
Male	13.429 <sup>a</sup>	0.706	12.008	14.850

a. Covariates appearing in the model are evaluated at the following values: Pretest = 11.43.  
**Source:** Researcher's Fieldwork, 2026.

Table 3: The estimated marginal means provide additional clarification on whether male and female students differed in their achievement in directed numbers after adjusting for their pre-test scores. The results show that both groups performed at a similar level.

After controlling for the covariate (pre-test score of 11.43), male students recorded an adjusted mean score of 13.429, while their female counterparts had an adjusted mean

score of 13.005. Although males appeared to have a slightly higher mean, the difference between the two groups is very small. The overlapping confidence intervals for males (12.008–14.850) and females (11.668–14.342) show clearly that the observed difference is not statistically meaningful.

This pattern aligns with the earlier statistical tests indicating that gender did not significantly influence students' post-test achievement. The closeness of the means and

the broad overlap in their confidence ranges confirm that any differences in performance between male and female students could be attributed to normal variation rather than the effect of gender. Consequently, the findings

support the null hypothesis that gender has no significant main effect on upper basic students' achievement in directed numbers in Egbeda Local Government Area of Oyo State.

**H<sub>02</sub>:** There will be no significant interaction effect of gender and logic-based teaching strategy on upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state.

<b>Table 4: Tests of Between-Subjects Effects of Gender and Logic-Based Teaching Strategy on Upper Basic Students' Achievement in Directed Numbers</b>						
Dependent Variable: Posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	569.852 <sup>a</sup>	4	142.463	12.584	0.000	0.534
Intercept	41.821	1	41.821	3.694	0.061	0.077
Pretest	451.145	1	451.145	39.852	0.000	0.475
Gender x Strategy	31.443	3	10.481	0.926	0.436	0.059
Error	498.107	44	11.321			
Total	9611.000	49				
Corrected Total	1067.959	48				

a. R Squared = 0.534 (Adjusted R Squared = 0.491)  
**Source:** Researcher's Fieldwork, 2026.

From Table 4: The Analysis of Covariance (ANCOVA) result on the interaction effect of gender and logic-based teaching strategy on

upper basic students' achievement in directed numbers in Egbeda local government area, Oyo state was;  $F_{(3; 44)} = 0.926, p > 0.05,$

partial  $\eta^2 = 0.059$ . This indicates that the difference in performance between the experimental and control groups did not vary in any meaningful way between male and female students. In other words, the teaching strategy did not advantage or disadvantage one gender over the other. The partial eta squared value of 0.059 further confirms that the proportion of variance explained by the

interaction is very small and practically negligible. Therefore, there was no significant interaction effect of gender and logic-based teaching strategy on upper basic students' achievement in directed numbers in Egbeda Local Government Area of Oyo State. This suggests that both male and female responded similarly to the instructional approaches used in the study.

**Table 5: Parameter Estimates of Gender and Logic-Based Teaching Strategy on Upper Basic Students' Achievement in Directed Numbers**

Dependent Variable: Posttest							
Parameter	B	Std. Error	t	Sig.	95% Confidence Interval		Partial Eta Squared
					Lower Bound	Upper Bound	
Intercept	3.734	1.724	2.166	0.036	.259	7.209	0.096
Pretest	0.875	0.139	6.313	0.000	.596	1.155	0.475
[Strategy=Logic-based Teaching Strategy] x [Gender=Female]	0.091	1.450	0.063	0.950	-2.832	3.014	0.000
[Strategy=Logic-based Teaching Strategy] x [Gender=Male]	-0.505	1.507	-0.335	0.739	-3.543	2.533	0.003
[Strategy=Traditional Teaching Strategy] x [Gender=Female]	-2.049	1.550	-1.321	0.193	-5.174	1.076	0.038

[Strategy=Traditional Teaching Strategy] x [Gender=Male]	0.000 <sup>a</sup>	0.000	0.000	0.000	0.000	0.000	0.000
<p>a. This parameter is set to zero because it is redundant. <b>Source:</b> Researcher’s Fieldwork, 2026.</p>							

Table 5: The parameter estimates from the ANCOVA model help to determine whether gender, in combination with the teaching strategy, contributed meaningfully to posttest performance when the influence of students’ pretest scores is taken into account.

The results show that the pretest score made a strong and statistically significant contribution to the posttest achievement ( $B = 0.875, p < 0.05$ ). This indicates that students who performed well initially were more likely to perform well after the intervention, regardless of their gender or the strategy used. This pattern suggests that prior knowledge remained a powerful predictor of learning outcomes in Directed Numbers.

Concerning the interaction between gender and teaching strategy, the findings demonstrate that none of the interaction terms were statistically significant. The coefficient for female students exposed to the logic-based teaching strategy ( $B = 0.091, p =$

$0.950$ ) shows no meaningful advantage or disadvantage when compared with the reference group. Similarly, the interaction effect for male students under the logic-based strategy ( $B = -0.505, p = 0.739$ ) was also not significant. The wide confidence intervals and extremely small partial eta squared values further confirm that these effects were trivial and did not meaningfully influence achievement.

The interaction effects for students taught with the traditional teaching strategy follow the same pattern. The estimate for female students ( $B = -2.049, p = 0.193$ ) did not reach statistical significance, indicating that their performance was not significantly different from that of male students in the traditional strategy group, which served as the reference category. Again, the effect size was very small, suggesting minimal practical impact.

Taken together, the insignificant interaction terms indicate that gender did not modify the

effect of either the logic-based or traditional teaching strategy on students’ achievement in directed numbers. In other words, male and female benefited similarly from each teaching approach. Therefore, based on the evidence presented in the parameter estimates, the findings support the null hypothesis that there was no significant

interaction effect of gender and logic-based teaching strategy on upper basic students’ achievement in directed numbers in Egbeda Local Government Area of Oyo State. This implies that differences in achievement were not jointly determined by the students’ gender and the type of teaching strategy used.

<b>Table 6: Estimated Marginal Means of Gender and Logic-Based Teaching Strategy on Upper Basic Students’ Achievement in Directed Numbers</b>						
Dependent Variable: Posttest						
Gender	Strategy	Mean	Std. Error	95% Confidence Interval		
				Lower Bound	Upper Bound	
Female	Logic-based Teaching Strategy	13.828 <sup>a</sup>	0.847	12.122	15.534	
	Traditional Teaching Strategy	11.688 <sup>a</sup>	1.075	9.520	13.855	
Male	Logic-based Teaching Strategy	13.232 <sup>a</sup>	0.917	11.384	15.079	
	Traditional Teaching Strategy	13.737 <sup>a</sup>	1.155	11.409	16.064	

a. Covariates appearing in the model are evaluated at the following values: Pretest = 11.43.  
**Source:** Researcher’s Fieldwork, 2026.

Table 6: The interaction between gender and teaching strategy was analyzed to determine whether male and female students performed

differently under the logic-based teaching strategy and the traditional teaching strategy after controlling for their pretest scores. The

adjusted means offer a clear picture of how each group responded to the two instructional approaches.

Under the logic-based teaching strategy, female students recorded an adjusted mean score of 13.83 (95% CI: 12.12–15.53), while male students had a mean of 13.23 (95% CI: 11.38–15.08). Although females performed slightly better, the difference of 0.60 was very small. When expressed as a Relative Percentage Gender Gap, this amounted to approximately 4.54%, indicating that gender differences under the logic-based strategy were minimal. This suggests that the logic-based strategy offered a balanced learning environment where both male and female students benefited almost equally.

In contrast, the traditional teaching strategy showed a wider performance gap. Female students obtained an adjusted mean score of 11.69 (95% CI: 9.52–13.86), whereas male students achieved a higher mean of 13.74 (95% CI: 11.41–16.06). The mean difference of 2.05 translated into a Relative Percentage Gender Gap of about 14.93%, representing the largest disparity between genders across the two strategies. This indicates that the

traditional strategy advantaged male students more than their female counterparts.

A comparison across the two strategies shows that male students performed better than female students particularly under the traditional strategy, where the gender gap was widest. However, the logic-based strategy significantly narrowed this gap, pointing to a more equitable teaching approach. Thus, the logic-based strategy appeared to support more balanced achievement between male and female students, whereas the traditional strategy widened gender differences.

Despite these observable differences, the statistical test of interaction showed that the combined effect of gender and teaching strategy on students' achievement in directed numbers was not significant. The Gender  $\times$  Strategy interaction yielded  $F_{(3; 44)} = 0.926$  with  $p > 0.05$ , indicating that the variations in performance between male and female students across the two strategies were not strong enough to reach statistical significance. Overall, while the logic-based strategy produced more balanced outcomes and the traditional strategy showed a larger gender gap, these differences did not translate

into a statistically meaningful interaction. This means that, although males and females showed slight variations in performance under different strategies, these variations were not substantial enough to conclude that gender and teaching strategy jointly influenced achievement in directed numbers.

### **Discussion of Findings**

There was no significant main effect of gender on upper basic students' achievement in directed numbers in Egbeda Local Government Area, Oyo State. Although male students had a slightly higher adjusted mean score than their female counterparts, this difference was minimal and statistically insignificant. This outcome indicates that, when provided with similar learning opportunities and exposed to the same instructional intervention, both male and female students demonstrated comparable levels of understanding and performance in directed numbers.

This outcome supports the inclusive focus of the logic-based instructional model, which is designed to present integer operations in a structured and accessible manner that benefits learners irrespective of gender. It

also aligns with contemporary research suggesting that when instructional strategies are clear, visual, and conceptually grounded, gender-related performance gaps in Mathematics tend to diminish (Raheem et al., 2025). Thus, the similarity in performance between male and female students strengthens the argument for adopting inclusive, reasoning-oriented pedagogies such as truth tables and logical coding, which emphasize understanding rather than rote procedures.

This finding aligns with broader patterns observed in several recent studies examining gender differences in Mathematics -related learning outcomes. For instance, Harun et al. (2024) reported no significant difference in students' mastery levels of integer operations based on gender following instructional intervention. Despite improvements in overall mastery after intervention, both male and female learners benefitted equally, demonstrating that effective instructional strategies help level the learning field across genders. Similarly, Cahyadi et al. (2023) found no gender-based discrepancies in students' use of pattern-finding strategies in solving mathematical problems. Both male

and female students showed comparable abilities to identify and apply patterns, reinforcing the view that mathematical reasoning and strategy use are not inherently gender-dependent.

Furthermore, Norhaslina et al. (2025) concluded that gender did not moderate students' performance when problem-based learning was used to enhance mathematical problem-solving skills. The PBL approach improved learners' outcomes regardless of gender, supporting the present study's result that when instructional methods are engaging, structured, and learner-centred, the influence of gender becomes insignificant.

This outcome differs from the findings of Adewale et al. (2025), who reported a significant main effect of gender and a notable interaction between gender and instructional strategy in upper basic students' achievement in basic operations. The disparity between the two studies may be attributed to differences in instructional emphasis and learning context. While the problem-solving approach actively engages learners in applying mathematical concepts through structured tasks, the logic-based strategy employed in the present study

emphasizes conceptual reasoning and symbolic representation, which may minimize gender-based performance differences by providing equal cognitive access to mathematical ideas.

Directed numbers involve rule-based operations that, when taught through structured and logical representations, may reduce reliance on prior experiences or intuitive strategies that sometimes favour one gender over the other. The absence of significant gender differences in this study suggests that the logic-based teaching strategy offers an equitable learning environment where both male and female students can engage with mathematical concepts on similar terms. This aligns with the goal of inclusive Mathematics instruction, which seeks to ensure that learning opportunities and outcomes are not determined by gender.

There was also no significant interaction effect of gender and logic-based teaching strategy on upper basic students' achievement in directed numbers in Egbeda Local Government Area of Oyo State. Although descriptive results indicated slight variations such as females performing

marginally better than males under the logic-based strategy and males outperforming females under the traditional strategy; these differences did not amount to a statistically meaningful interaction effect. In essence, neither strategy created a unique advantage nor disadvantage for any gender when prior knowledge was taken into account. This finding reinforces the conclusion that logic-based instructional practices such as truth tables and coding frameworks provide equitable learning opportunities for all students by minimizing variability associated with gender (Raheem et al., 2025). The absence of interaction effects suggests that both male and female learners responded similarly to the structure, clarity, and inclusiveness of the logic-based method.

This outcome corresponds with growing evidence in Mathematics education that gender alone does not determine how students respond to instructional strategies, especially when the teaching approach is structured, scaffolded, and concept-focused. For example, Anggraeni et al. (2025) showed that well-designed instructional supports for integer operations raised achievement for both male and female learners without

significant gender disparities. Similarly, Harun et al. (2024) reported no significant gender differences in mastery levels after intervention, reinforcing the idea that conceptual support benefits learners equally.

The absence of an interaction effect in the present study also aligns with findings from meta-analytical research on the use of manipulatives in teaching integers. Lacaba (2025) reported that manipulative-based instruction produced substantial improvements in students' understanding of integer operations regardless of gender. Such techniques help reduce misconceptions related to negative signs, operations involving two negatives, and symbolic interpretation; difficulties that commonly affect learners across genders. Additional support for this result comes from studies examining mastery levels and conceptual understanding of integer operations. Research has shown that learning difficulties such as misinterpreting integer symbols, confusing addition and subtraction rules, or misusing representations occur across genders rather than being gender-specific (Harun et al., 2024). For instance, Toxtle-Colotl et al. (2025) revealed that students'

difficulties with representations and properties of integers cut across both male and female learners. Similarly, Owusu et al. (2023) concluded that errors in integer operations among pre-service teachers stemmed primarily from conceptual misunderstandings rather than gender-related reasoning differences. Studies on mathematical reasoning and strategy use further reinforce the conclusion that gender does not significantly moderate instructional effects. Cahyadi et al. (2023) found no meaningful gender differences in students' abilities to identify and apply patterns in problem solving, while Norhaslina et al. (2025) reported equal benefits for both genders under problem-based learning. Even in studies where slight gender-related tendencies were observed, Abdussakir et al. (2024) noted that such differences were inconsistent and insufficient to predict performance across mathematical domains.

Overall, the findings of the present study mirror these broader trends in Mathematics education research. The logic-based strategy produced a more balanced performance between male and female students, narrowing the gender gap substantially. In

contrast, the traditional strategy showed wider but statistically insignificant differences. Although observable patterns existed, statistical analysis confirmed that the combined influence of gender and instructional strategy did not significantly predict achievement in directed numbers.

This outcome contrasts with Adewale et al. (2025), who reported a significant interaction between gender and instructional strategy in favour of male students. The difference between the two studies may be explained by the nature of the instructional approaches employed. While problem-solving techniques emphasize multi-step reasoning and procedural decision-making, the logic-based strategy emphasizes structured rules, symbolic consistency, and clear operational patterns that may be uniformly accessible to both male and female learners.

Taken together, the absence of a significant interaction effect in the present study suggests that the logic-based teaching strategy promotes a more inclusive learning environment by minimizing gender-related differentials in achievement. By focusing on logical relationships and systematic representation of directed numbers, the

strategy reduces dependence on intuitive guessing or trial-and-error approaches that can sometimes accentuate gender disparities. Consequently, both male and female students benefitted from the instructional method without one group gaining a distinct advantage over the other.

### Conclusion

Based on the findings of this study, it was concluded that neither the gender nor logic-based teaching strategy independently or jointly produced a significant effect on students' achievement in directed numbers among upper basic students in Egbeda Local Government Area of Oyo State. Although gender-related variations were observed: under the logic-based strategy, female and male students performed almost equally with only a very small gap while the Traditional Strategy produced a wider disparity, favoring male students. Notably, the logic-based strategy substantially narrowed the gender gap, whereas the traditional strategy widened it; however, these differences, though visible descriptively, were not strong enough to be statistically meaningful. Ultimately, students' achievement in directed numbers remained largely unaffected by the gender or

instructional strategy used, suggesting that other factors beyond teaching approach and gender may play a more influential role in shaping students' learning outcomes in this mathematical concept.

### Recommendations

Based on the findings of this study, the following recommendations were made:

1. Mathematics teachers should adopt inclusive and gender-neutral classroom practices, as gender was not found to significantly influence students' achievement in directed numbers.
2. Logic-based and learner-centered instructional strategies should be integrated alongside existing teaching methods to support conceptual understanding and promote equity in Mathematics learning.

### References:

1. Abdussakir, A., Chabibah, R., Yahya, F. H., & Ali, F. (2024). Between gender and academic achievement: Creative thinking in Mathematics problem solving among junior high school students. *Beta: Jurnal Tadris Matematika*, 17(2), 205–222.

2. Adewale, O. E., Raheem, T. R., & Sam-Kayode, C. O. (2025). Effect of problem-solving technique on upper basic school students' academic achievement in basic operations. In Proceedings of the International Conference of Education Dialogue Association (EDUDIA). University of Education, Winneba.
3. Anggraeni, F., Andayani, S., & Rahmawati, D. (2025). Analysis of students' mastery levels in using integer operations in elementary school Mathematics learning. *International Journal of Multidisciplinary Research of Higher Education (IJMURHICA)*, 8(1), 1–13.
4. Cahyadi, M. R., Ariansyah, F., & da Silva Santiago, P. V. (2023). Analysis of skills using pattern-finding strategies in solving mathematical problems in view of gender differences. *Delta-Phi: Jurnal Pendidikan Matematika*, 1(1), 12–22.
5. Gyampoh, S. A., Nyarko, J., & Agyeman, K. D. (2020). Improving the performance of basic school pupils in addition and subtraction of integers using rectangular cut-out number line: A case of a Ghanaian basic school. *IOSR Journal of Mathematics (IOSR-JM)*, 16(3), 21–28.
6. Harun, N. A. J., Cuevas, K. G. A., Sagdi, L. J. D. S., Sapilin, A. A., Nasilon, N. Y., Kadil, M., Alviar, J. V., & Solon, L. J. V. (2024). Impact of intervention on students' mastery level and analysis of misconceptions in operations on integers. *International Journal of Multidisciplinary: Applied Business and Education Research*, 5(2), 411–422.
7. Ikyanyi, M. I., Anyagh, P. I., & Abari, M. T. (2023). Effect of Polya's problem-solving approach on upper basic education students' attitude towards algebra in Makurdi Metropolis, Benue State, Nigeria. *Village Math Educational Review*, 5(1), 40–53.
8. Jangde, S., & Ahmad, M. A. (2025). Integrating Sustainability into Equal Education Opportunities. In *Environmental Landscape and Sustainable Biodiversity for Healthy Green Growth* (pp. 97-103). Cham: Springer Nature Switzerland.
9. Kwakye, D. O., Alphaa, M. A., Agyei, E., Larbi, E. A., Anane, J. K., & Domonaamwin, B. C. (2022). Complete integers: Integers and its applications (Vol. 1). White Falcon.
10. Lacaba, K. G. (2025). Manipulatives in teaching and learning integers: A meta-

analysis. *EIKI Journal of Effective Teaching Methods*, 3(2), 149–157.

11. Norhaslina, N., Oktafia, M., & Noperta, N. (2025). Exploring the effectiveness of problem-based learning on mathematical problem-solving: A gender perspective. *Journal of Authentic Research on Mathematics Education*, 7(1), 1–10.

12. Owusu, A., Bornaa, C., Kwakye, D., & Iddrisu, A. (2023). Pre-service Mathematics teachers' errors and misconceptions of integer operations. *Journal of Statistics and Mathematical Concepts*, 1(2), 1–19.

13. Oyo State Universal Basic Education Board. (2025). 2024/2025 number of public junior secondary schools in Egbeda Local Government Area, Ibadan and their respective JSS II enrolments. Oyo State SUBEB.

14. Phalguni, S., Saniya, M., Akshay, G., Vinay, B., & Pranavraj, G. (2023). Truth table generator. *International Research Journal of Engineering and Technology (IRJET)*, 10(1), 394–397.

15. Raheem, T. R., Adewale, O. E., & Sam-Kayode, C. O. (2025). Promoting inclusive Mathematics instruction through logical truth tables and coding in integer

operations. In Proceedings of the 2nd Postgraduate College International Multidisciplinary Conference. Lead City University.

16. Rosyidah, A. N. K., Jiwandono, M. I. S., Oktavianti, I. S., & Gunawan, G. I. (2021). Misconceptions and errors in integer operations: A study in preservice elementary school teachers (PGSD). *Journal of Physics: Conference Series*, 1779(1), 012078. <https://doi.org/10.1088/1742-6596/1779/1/012078>

17. Toxtle-Colotl, A., Nieto-Ruiz, E., & Juárez-López, J. A. (2025). Multidimensional analysis of conceptual understanding of integer addition and subtraction. *International Journal of Educational Methodology*, 11(1), 97–112.

Received: Feb 10, 2026

Accepted: Mar 06, 2026

Published: Apr 01, 2026

Advancing Inclusive Mathematics Education through Logic-Based Instruction: Gender Perspectives on Upper Basic Students' Achievement in Directed Numbers in Egbeda, Oyo State by Tunde Rasheed Raheem and Christianah Olajumoke Sam-Kayode is licensed under a Creative Commons Attribution 4.0 International License (CC BY 4.0) © 2026, and is published by the ICERT.