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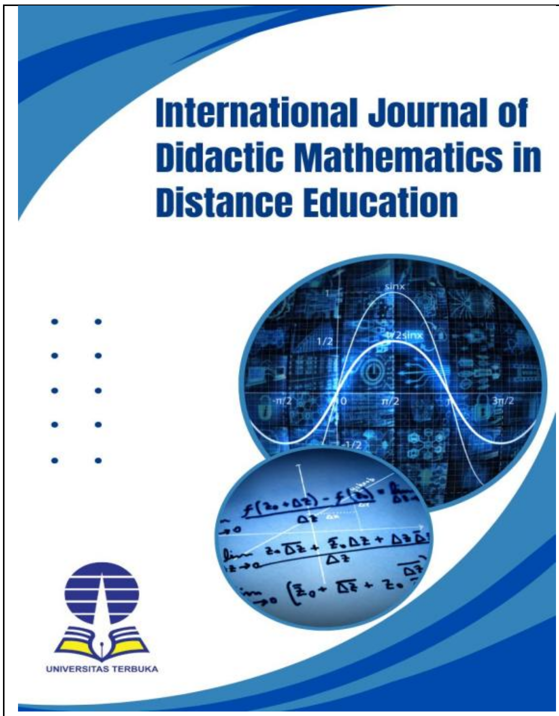

Differentiated instruction, achievement, and gender equity in secondary mathematics: A didactical resource for distance and digital learning design

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Differentiated instruction, achievement, and gender equity in secondary mathematics: A didactical resource for distance and digital learning design

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Abstract
Differentiated instruction (DI) is widely promoted for addressing students' diverse readiness, interests, and learning profiles in mathematics classrooms; however, evidence of its effectiveness remains dominated by face-to-face settings. This study examined the effect of differentiated instruction on senior secondary school students' mathematics achievement, with gender as a moderating variable, and considered its implications for distance and digital mathematics learning. A pretest-posttest non-equivalent control group quasi-experimental design involved two intact classes from two public secondary schools in the Ijebu Education Zone, Ogun State, Nigeria. The experimental group ($n = 46$) received differentiated instruction, while the control group ($n = 59$) received conventional lecture-based instruction. Data were collected using a 50-item Mathematics Achievement Test with a KR-20 reliability coefficient of 0.84 and analyzed using descriptive statistics and ANCOVA at the .05 significance level. Results showed a significant treatment effect on mathematics achievement ($F(1, 100) = 13.653$, $p < .001$, partial $\eta^2 = .120$), while gender and the treatment-by-gender interaction were not significant. Supplementary document analysis indicated that readiness-, interest-, and product-based differentiation can be adapted to digital formats, whereas teacher-observed flexible grouping requires structured, data-informed alternatives. These findings demonstrate the effectiveness and gender inclusivity of DI while providing practical didactical insights for designing adaptive, responsive, and digitally mediated mathematics learning environments in distance education contexts.

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1. Introduction

Mathematics occupies a foundational place in human intellectual life. It is a discipline concerned with patterns of structure, change, and space, and it functions simultaneously as a tool for communication and as a method of reasoning grounded in systematic, evidence-based argument (Ndia et al., 2020). Learning to communicate mathematically, through diagrams, equations, graphs, and tables, is among the central goals of mathematics education, enabling students to organize and express their thinking both orally and in writing.

Nigeria's National Policy on Education identifies reasoning, problem-solving, and communication as core objectives of school mathematics (Federal Republic of Nigeria, 2013). In practice, however, mathematics is frequently experienced by students as difficult and unappealing, and is often reported as students' least-favored subject (Ndia et al., 2020). Multiple interacting factors, students themselves, teachers, instructional methods, and the learning environment, have been implicated in persistently low learning outcomes. A recurring tension is that while teachers often work toward a homogeneous pace of instruction, students in any given classroom differ markedly in prior knowledge, skills, cognitive processing, interests, learning pace, and motivation (Marks et al., 2021). Teaching without accounting for this diversity can leave many students underserved, a pattern well documented in Nigerian mathematics classrooms where instruction is often delivered uniformly regardless of individual variation.

DI is one response to this diversity. It is a pedagogical approach that identifies each student's learning needs and adapts content, process, product, and learning environment to maximize academic potential (Bal, 2023). Since Carol Ann Tomlinson introduced the framework in the United States in the 1990s, DI has been adopted internationally as a way of responding to student diversity (Tomlinson, 2003). Three facets of diversity anchor the framework: readiness (a student's current proximity to specific knowledge and skills), interest (what engages a student's attention), and learning profile (a student's preferred way of taking in, exploring, and expressing content) (Tomlinson & Imbeau, 2010).

Analyzing how teachers actually enact DI, however, requires attention not only to what is differentiated but to the resources through which differentiation is accomplished — the tasks, materials, and representations a teacher selects, combines, and adapts for a given group of students. The documentational approach to didactics offers a complementary lens for this purpose: it treats a teacher's instructional resources as material that is continuously reworked into usable "documents" through cycles of use, reflection, and revision, and it has been used specifically to analyze how teachers sustain or struggle to sustain differentiation once the resources available to them change, including in remote and hybrid teaching arrangements (Matranga & Silverman, 2022). Reading the tiered tasks, flexible groupings, and varied assessments used in the present study through this resource-oriented lens makes it possible to ask a more specific question than whether DI "works": which features of the differentiated resources used here are portable to a distance or digitally mediated mathematics course, and which depend on face-to-face conditions that a distance format cannot reproduce.

In mathematics specifically, differentiating instruction requires teachers to vary tasks by skill level, for example, offering concrete manipulatives for some students learning fractions while others engage in abstract reasoning tasks, and to vary pace and strategy, such as inquiry-based learning for students who progress quickly and more structured, direct instruction for students who need additional support (Tomlinson, 2003). Differentiating products can involve allowing students to demonstrate understanding through tests, assignments, or presentations, while an encouraging and flexible classroom climate supports motivation and engagement (Bal, 2023). Successfully implementing DI, however, is demanding: it requires both deep content knowledge and the pedagogical skill to design and deliver differentiated lessons that meet a wide range of student needs (Meutstege et al., 2023). Teachers frequently report that they value differentiation in principle but struggle to sustain it in practice once curricular, assessment, and time pressures are taken into account (Hayden et al., 2024).

Empirical evidence on DI in mathematics remains comparatively thin and, at times, inconsistent. Faber, Glas, and Visscher (2018) found no statistically significant overall effect of DI on achievement, though a positive association between the degree of differentiation implemented and achievement gains. More recent quasi-experimental and design-based studies show a similarly mixed but generally positive pattern: Ndia et al. (2025) found that differentiated approaches interacted with students' mathematical disposition to shape communication outcomes, while professional-development studies indicate that even well-supported teachers require sustained coaching to translate DI principles into consistent tiered classroom practice (Cody et al., 2023), and studies of teacher candidates preparing to differentiate STEM instruction with digital tools report that the technical skill to build differentiated resources does not automatically translate into confident classroom use (Estaiteyeh & DeCoito, 2023a, 2023b). A systematic review of differentiation practices in primary education similarly found generally positive, though modest and unevenly reported, cognitive effects (Deunk et al., 2018), and a review focused on secondary education reached comparable conclusions of a positive but heterogeneous evidence base (Adriani et al., 2026; Rahman et al., 2024; Smale-Jacobse et al., 2019).

Gender is a second recurring variable in this literature. Opinions on gender-based achievement in mathematics remain divided: some large-scale analyses report a persistent gap favoring boys once reading-related bias in assessment is controlled for (Lu et al., 2023), while others report that the gap has narrowed, reversed, or varies by school-effectiveness context in specific national settings (Oregui-González et al., 2024) and widens over the course of secondary schooling for reasons related to motivation and self-perception rather than ability (Ellison & Swanson, 2023; Bohrnstedt et al., 2024). Even at the elementary level, gender differences in specific mathematical sub-skills such as fraction learning have been linked to spatial ability and mathematics anxiety rather than to differentiation practice itself (Zhang et al., 2024). Teachers have also been shown to respond differently to boys' and girls' struggles with mathematics, often normalizing boys' difficulty as a matter of practice while questioning girls' capability more directly, a pattern that shapes how each group comes to view mathematics as a masterable skill (Awofala, 2017). Prior Nigerian studies on gender and differentiated instruction report mixed patterns, with some finding no significant gender difference in the benefits students receive from differentiated approaches (Ojaleye & Awofala, 2018) and others reporting a modest gap favoring boys (Awofala, 2016).

Adeniran et al. (2025) found that differentiated instruction significantly raised primary learners' science achievement with no significant gender difference, a pattern consistent with Bal's (2023) finding that differentiation improved both achievement and attitudes for secondary mathematics learners regardless of gender. Most of this international literature, however, concentrates on urban schools or general populations and pays limited attention to specific educational zones such as Ijebu in Ogun State, and the relationship between gender and differentiated instruction remains ambiguous across studies — some report equal benefit for both genders, others a gap favoring one, and many do not disaggregate by gender at all.

A further limitation of this literature, and the one this study addresses most directly, is that virtually all of the evidence on DI in mathematics, including the studies reviewed above, was generated in conventional, co-present classrooms. Differentiation in a face-to-face setting draws on resources that are difficult to transfer directly to distance or digitally mediated instruction: a teacher's real-time reading of body language and spontaneous questioning to gauge readiness, on-the-spot regrouping of students, and immediate verbal feedback. Studies of teachers attempting to differentiate mathematics instruction in remote and hybrid arrangements report that these resources are precisely what breaks down first, and that digital tools can either substitute for or actively hinder differentiation depending on how they are documented and used by the teacher (Matranga & Silverman, 2022). Adaptive digital platforms that route students to different tasks based on demonstrated readiness offer one partial substitute and have shown measurable gains in personalized mathematics learning even at early grade levels (Bang et al., 2023), but such platforms still require teachers to possess the pedagogical-digital competence to select, sequence, and interpret them meaningfully (Ndia et al., 2025; Estaiteyeh & DeCoito, 2023a). There is therefore a gap not simply in whether DI improves mathematics achievement, but in which specific features of a validated DI intervention are structurally portable to distance and digital formats and which are not.

This study's objectives are to: (i) examine how differentiated instruction affects senior secondary school students' mathematical achievement; (ii) determine how gender affects senior secondary school students' mathematical performance under differentiated instruction; (iii) ascertain how treatment and gender combine to affect senior secondary school students' mathematical performance; and (iv) use the documentational-resource lens described above to classify which components of the validated differentiated intervention can serve directly as design principles for distance and digitally mediated mathematics learning, and which depend on conditions specific to the face-to-face classroom.

2. Methods

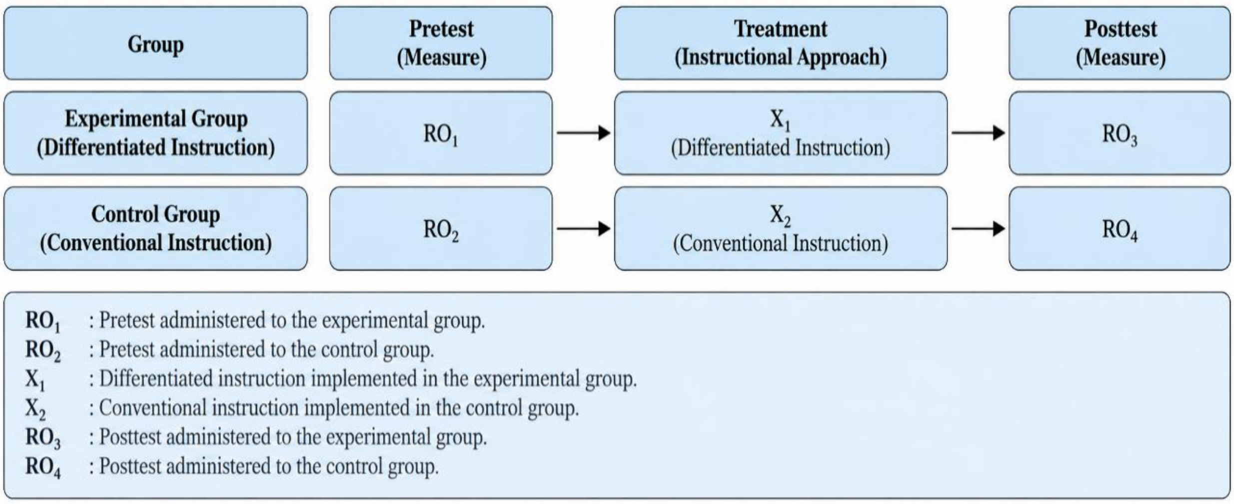
2.1 Research Design

This study employed a pretest–posttest, non-randomized control group quasi-experimental design to examine the effect of differentiated instruction on secondary school students' mathematics achievement while considering gender differences in learning outcomes. A quasi-experimental design was considered appropriate because the study was conducted in natural classroom settings where students were already organized into intact classes, making individual random assignment impractical. The design enabled the researchers to compare changes in mathematics achievement between students exposed to differentiated instruction and those receiving the comparison instructional approach. The study was conducted in the Ijebu Education Zone of Ogun State, Nigeria.

The design consisted of an experimental group and a control group, both of which completed mathematics achievement measures before and after the instructional intervention. In the design notation, RO_1 and RO_2 represent the pretest measurements administered to the experimental and control groups, respectively, while RO_3 and RO_4 represent their corresponding posttest measurements. X_1 denotes the differentiated instruction implemented in the experimental group, whereas X_2 represents the instructional approach used in the control group. The pretest scores provided baseline information on students' initial mathematics achievement, while the posttest scores were used to determine changes following the intervention (See Figure 1). Gender was additionally considered in the analysis to examine whether the instructional effects were comparable across male and female students, thereby providing evidence concerning the equity dimension of differentiated mathematics instruction.

Figure 1

Pretest–Posttest Non-Randomized Control Group Quasi-Experimental Design



2.2 Population and Sample

The population of this study comprised all students enrolled in Senior Secondary School Two (SS2) mathematics classes in public secondary schools within the Ijebu Education Zone, Ogun State, Nigeria. SS2 students were considered appropriate for the study because they were actively engaged in senior secondary mathematics instruction and had sufficient prior mathematical experience to participate in the instructional intervention. The study focused on public secondary schools to maintain a relatively comparable educational context in terms of curriculum, instructional expectations, and school administration.

The sample consisted of 105 SS2 students from two coeducational public secondary schools selected through purposive sampling. Schools were eligible if they had been registered for the Senior School Certificate Examination (WAEC and NECO) for at least five years, employed at least one qualified mathematics teacher, and obtained administrative approval and voluntary participation from the cooperating teachers and students. The sample comprised 57 female and 48 male students. Of the 105 participants, 46 students (25 male and 21 female) formed the experimental group and received differentiated instruction, while the remaining 59 students (23 male and 36 female) constituted the control group. The use of intact classes preserved the natural classroom organization and was consistent with the quasi-experimental design adopted in the study.

2.3 Data Collection

Primary data were collected using the Mathematics Achievement Test (MAT), a 50-item multiple-choice instrument with four options (A-D) per item, compiled from past questions set by the National Examination Council (NECO), the West African Examination Council (WAEC), and the National Business and Technical Examinations Board (NABTEB) for 2022-2025. Each correct response was worth two points. Three specialists from the Measurement and Evaluation Unit of Olabisi Onabanjo University and the Mathematics Education Unit of Tai Solarin University of Education validated the instrument. Reliability, estimated using the Kuder-Richardson 20 (KR-20) formula appropriate for dichotomously scored items, was 0.84.

Regular mathematics teachers in the participating schools were trained by the researchers to serve as research assistants and delivered the treatment using researcher-developed lesson plans. The experimental group received differentiated instruction (DI) addressing students' readiness, interest, and learning profile through tiered tasks, flexible grouping, and varied assessment formats; the control group received conventional lecture-method (LM) instruction using lesson plans that mirrored the same learning objectives. Treatment ran for five weeks in each school, from week two to week six, with the pretest administered in week one and the posttest in week six. Descriptive statistics (mean and standard deviation) and inferential statistics (Analysis of Covariance) were used to analyze the study questions and hypotheses at the 0.05 level of significance. All procedures complied with the participating schools' ethical standards.

The study was guided by two research questions: (i) How do the mean achievement scores of students who receive differentiated mathematics instruction differ from those who receive traditional instruction? (ii) How do male and female students' mean mathematics achievement scores differ within the experimental group? Three corresponding null hypotheses were tested at the 0.05 level of significance: (H1) treatment (differentiated instruction) has no significant effect on senior secondary students' mathematics achievement; (H2) gender has no significant effect on senior secondary students' mathematics achievement under differentiated instruction; (H3) the interaction of treatment and gender has no significant effect on senior secondary students' mathematics achievement.

2.4 Data Analysis

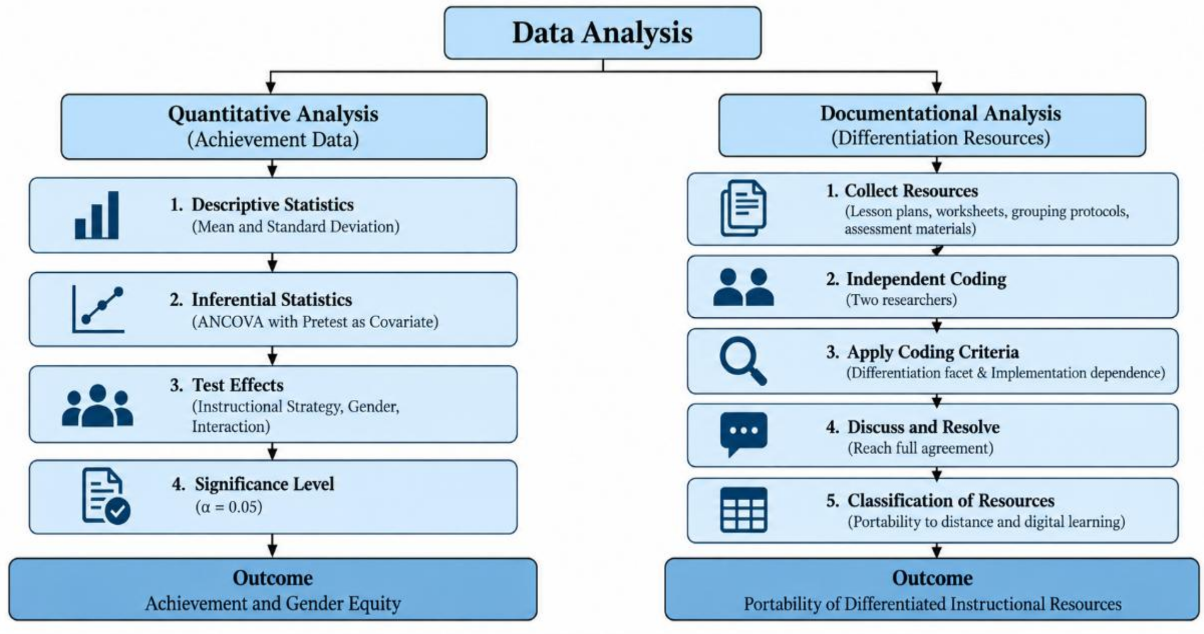
The data were analyzed using both quantitative and qualitative procedures in accordance with the study objectives. For the quantitative analysis, descriptive statistics, including the mean and standard deviation, were used to summarize students' mathematics achievement across the experimental and control groups. Inferential analysis was conducted using Analysis of Covariance (ANCOVA), with pretest scores entered as the covariate to statistically control for initial differences in mathematics achievement between the two intact groups. ANCOVA was used to examine the effect of differentiated instruction on posttest achievement and to determine whether achievement differed by gender and whether an interaction existed between instructional strategy and gender. All hypotheses were tested at the 0.05 level of significance.

To complement the achievement analysis and address the study objective concerning the potential use of differentiated instruction in distance and digital mathematics learning, a qualitative document analysis was conducted on the instructional resources developed and used with the experimental group. The analyzed materials included differentiated lesson plans, tiered worksheets, grouping protocols, and assessment materials. Guided by the documentational approach to didactics (Matranga & Silverman, 2022) and the differentiation framework of Tomlinson and Imbeau (2010), each resource was examined according to two dimensions. First, the analysis identified the differentiation facet represented by the resource, including readiness, interest, learning profile, process, or product. Second, each resource was examined to determine whether its implementation depended primarily on the teacher's real-time face-to-face observation and adjustment or whether its differentiation features could be specified in advance and therefore potentially implemented through distance or digital learning environments.

The documents were coded independently by two members of the research team to strengthen the consistency of the classification process. For example, a teacher's spontaneous regrouping of students in response to observed difficulties was classified as highly dependent on real-time classroom interaction, whereas a tiered worksheet assigned according to pretest performance was classified as more readily specifiable in advance and potentially transferable to a digital environment. Any differences in coding were discussed by the two researchers until agreement was reached. The resulting classifications were subsequently used to examine the portability of differentiated instructional resources to distance and digital learning, independently of the quantitative achievement outcomes. Thus, the quantitative analysis provided evidence regarding the effectiveness and gender-related outcomes of differentiated instruction, whereas the document analysis provided complementary evidence regarding how the instructional resources might inform the design of differentiated mathematics learning in digitally mediated settings.

Figure 2

Data Analysis Framework of the Study



2.5 Ethical Clearance

This study involved minors (senior secondary school students) and was therefore subject to institutional and school-level ethical review prior to data collection. Ethical approval was obtained from the Research Ethics Committee of Tai Solarin University of Education. Written permission to conduct the study was also obtained from the management of the two participating public secondary schools in the Ijebu Education Zone, Ogun State, Nigeria.

Because participants were minors, informed consent was obtained from parents or legal guardians on behalf of their children prior to participation, and assent was separately obtained from the students themselves. Participants and their guardians were informed of the purpose of the study, the voluntary nature of participation, and their right to withdraw at any stage without penalty. No identifying information about individual students is reported in this manuscript, and all data were anonymized prior to analysis. The study was conducted in accordance with the ethical standards of the participating institutions and with the Declaration of Helsinki.

3. Results and Discussion

3.1 Results

3.1.1 Implementation of the Instructional Intervention

The instructional intervention was implemented in the intact SS2 mathematics classes assigned to the experimental and control groups. Before the intervention commenced, the cooperating mathematics teachers were briefed on the objectives, instructional procedures, lesson sequence, and assessment requirements of the study.

Particular attention was given to ensuring that both groups addressed the same mathematical topics, learning objectives, and approximate instructional duration so that the principal difference between the groups concerned the instructional approach. Students in the experimental group received differentiated instruction, whereas those in the control group were taught through the conventional whole-class approach normally used in the participating school. The intervention followed a structured sequence consisting of pre-assessment, identification of learner differences, instructional planning, differentiated implementation, ongoing assessment and regrouping, consolidation, and post-assessment (See Figure 3).

Stage 1: Pre-assessment and identification of students' readiness. Before differentiated instruction began, students completed the mathematics achievement pretest. In addition to providing baseline achievement data for the quasi-experimental analysis, the results were used as an initial indicator of students' readiness for the mathematical content to be taught. Students' responses were examined to identify differences in prerequisite knowledge, conceptual understanding, procedural competence, and common misconceptions. Rather than treating the class as a homogeneous group, the teacher used this information to establish initial readiness profiles. Students requiring substantial support, those demonstrating moderate understanding, and those showing relatively advanced readiness could therefore be provided with learning tasks of appropriate complexity. These groupings were flexible instructional arrangements rather than permanent ability categories.

Stage 2: Planning differentiated learning resources. Based on the pre-assessment information, the teacher prepared differentiated lesson plans and instructional resources before classroom implementation. The same core learning objectives were maintained for all students, but the pathways through which students engaged with the mathematical ideas were varied. Tiered worksheets were prepared at different levels of scaffolding and complexity. For students requiring greater support, activities included more explicit prompts, worked examples, visual representations, and guided questions. Students demonstrating moderate readiness worked with tasks requiring greater independence and application, while students with stronger prior understanding were provided with more challenging problems requiring reasoning, justification, comparison of strategies, or transfer to unfamiliar situations. Differentiation therefore did not imply different curricular goals; rather, it provided different levels of instructional support and challenge for achieving common mathematical objectives.

Stage 3: Introduction and whole-class orientation. Each lesson began with a short whole-class activity in which the teacher introduced the learning objective, activated relevant prior knowledge, and presented the central mathematical problem or concept. This stage provided a common conceptual starting point for all students. The teacher used short questions, examples, representations, or familiar situations to determine whether students could connect previous knowledge with the new topic. Students were encouraged to explain their initial ideas rather than simply provide numerical answers. The teacher observed their responses and compared them with the readiness information obtained from the pre-assessment. Where necessary, the initial grouping or task assignment was adjusted before students moved into differentiated activities.

Stage 4: Differentiated learning activities. Students subsequently engaged with tasks corresponding to their identified learning needs. Differentiation was implemented through combinations of readiness, interest, learning profile, process, and product. Readiness-based differentiation was reflected primarily in the level of scaffolding and complexity of mathematical tasks. Where appropriate, interest was incorporated by allowing students to engage with mathematical problems presented through different contexts while retaining the same underlying mathematical concept. Learning-profile considerations were addressed through variations in representations and modes of engagement, including symbolic, numerical, graphical, verbal, and collaborative activities. Differentiation of process occurred through individual work, paired problem solving, small-group discussion, guided teacher support, and independent exploration. Product differentiation allowed students, where appropriate, to demonstrate understanding through different forms such as completed solutions, explanations, representations, or presentations of problem-solving strategies.

Stage 5: Flexible grouping and teacher facilitation. Flexible grouping constituted an important component of the experimental treatment. Students were not assigned permanently to one achievement group. Instead, grouping was adjusted according to the requirements of a particular task and evidence of students' developing understanding. During group activities, the teacher moved between groups, asked probing questions, provided scaffolding, clarified misconceptions, and extended tasks for students who demonstrated early mastery. For example, a student initially receiving a highly scaffolded worksheet could move to a less structured task after demonstrating sufficient understanding. Conversely, students encountering unexpected difficulty could receive additional prompts, representations, or peer support. This flexibility was intended to prevent differentiated instruction from becoming static ability tracking and to maintain opportunities for progression among all students.

Stage 6: Formative assessment and instructional adjustment. Assessment was embedded throughout the instructional process rather than being restricted to the end of the intervention. The teacher monitored students' written work, mathematical explanations, responses to questions, group discussions, and solutions to short formative tasks. Evidence obtained from these activities informed immediate instructional decisions. Misconceptions shared by several students could be addressed through a brief whole-class explanation, while difficulties specific to individual students or groups were addressed through targeted support. Students who had already demonstrated mastery were given extension tasks rather than repeatedly completing similar exercises. Thus, formative assessment functioned as the link between the identification of learner differences and subsequent instructional adaptation.

Stage 7: Consolidation and demonstration of learning. Toward the end of each lesson, students returned to a common mathematical focus. Selected students or groups presented solutions, compared strategies, justified procedures, or discussed errors

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encountered during the activities. The teacher synthesized these contributions and explicitly connected the differentiated activities to the common lesson objectives. Short exit tasks or concluding questions were used to determine students' level of understanding and to inform planning for the subsequent lesson. This consolidation stage was particularly important because it ensured that differentiation did not fragment the curriculum into unrelated learning experiences; all students ultimately worked toward shared mathematical concepts and expected learning outcomes.

Stage 8: Implementation in the control group. The control group studied the same mathematical content over a comparable instructional period but received conventional mathematics instruction. Lessons generally involved teacher explanation and demonstration of mathematical procedures, presentation of worked examples, whole-class questioning, and individual practice using common exercises. Students typically received the same instructional materials and tasks regardless of differences in readiness, interest, or learning profile. The teacher provided clarification when students experienced difficulties, but systematic use of pre-assessment-based tiering, flexible grouping, differentiated resources, and planned variation in learning processes or products was not incorporated. Maintaining comparable content and instructional duration while varying the instructional approach enabled the study to examine the relative effect of differentiated instruction on mathematics achievement.

Stage 9: Post-assessment and documentation of instructional resources. At the completion of the instructional period, students in both groups completed the mathematics achievement posttest under comparable conditions. The posttest provided the outcome data used to examine differences in mathematics achievement after controlling for initial pretest performance and to investigate whether the effects of the instructional strategy differed by gender. Following implementation, the differentiated lesson plans, tiered worksheets, grouping protocols, and assessment materials used in the experimental group were retained for the supplementary documentational analysis. These resources were subsequently examined to identify the facets of differentiation they embodied and the extent to which their implementation depended on real-time face-to-face teacher observation or could be specified in advance. This final analysis provided the basis for considering how the differentiated instructional resources developed in the classroom intervention might be adapted or transferred to distance and digitally mediated mathematics learning environments.

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Figure 3

Implementation Flow of Differentiated Instruction in Mathematics Learning

3.1.2 Descriptive Analysis of Mathematics Achievement

Descriptive statistics were first used to provide an overview of students' mathematics achievement before and after the instructional intervention. Mean scores, standard deviations, and mean differences were examined to describe achievement changes between the experimental and control groups and to provide a basis for subsequent inferential analysis. To determine whether the observed differences were statistically significant after controlling for students' initial achievement, ANCOVA was conducted to test Hypothesis One, which stated that differentiated instruction has no significant effect on senior secondary students' mathematics achievement.

Table 1

Pre-treatment and post-treatment achievement scores by treatment group

Description	Experimental Pretest	Experimental Posttest	Control Pretest	Control Posttest
N	46	46	59	59
Mean	11.23	18.67	9.93	10.51
Standard Deviation	3.277	5.416	1.953	1.808
Mean Difference	7.44		0.58	

As shown in Table 1, the experimental group receiving differentiated mathematics instruction scored a mean of 11.23 (SD = 3.277) on the pretest and 18.67 (SD = 5.416) on the posttest, a mean difference of 7.44. The control group receiving conventional instruction scored a mean of 9.93 (SD = 1.953) on the pretest and 10.51 (SD = 1.808) on the posttest, a mean difference of 0.58. Students in the experimental group thus showed substantially larger gains than those in the control group, indicating that differentiated instruction was more effective than conventional teaching in this sample.

3.1.3 Descriptive Statistics of Experimental-Group Students by Gender

Descriptive statistics were next used to provide an overview of male and female students' mathematics achievement within the experimental group before and after the instructional intervention. Mean scores, standard deviations, and mean differences were examined to describe achievement changes by gender and to provide a basis for subsequent inferential analysis (See Table 2). To determine whether the observed differences were statistically significant after controlling for students' initial achievement, ANCOVA was conducted to test Hypothesis Two, which stated that gender has no significant effect on senior secondary students' mathematics achievement under differentiated instruction.

Table 2

Descriptive statistics of experimental-group respondents by gender

Description	Male Pretest	Male Posttest	Female Pretest	Female Posttest
N	25	25	21	21
Mean	8.62	16.00	9.25	15.80
Standard Deviation	2.116	5.252	1.726	5.298
Mean Difference	7.38		6.55	

As shown in Table 2, male students scored a mean of 8.62 (SD = 2.116) on the pretest and 16.00 (SD = 5.252) on the posttest, a mean difference of 7.38. Female students scored a mean of 9.25 (SD = 1.726) on the pretest and 15.80 (SD = 5.298) on the posttest, a mean difference of 6.55. The two groups' gains were of broadly similar magnitude; the small numerical difference in mean gain is examined for statistical significance in Hypothesis Two below.

3.1.4 Effect of Differentiated Instruction on Mathematics Achievement

Analysis of covariance (ANCOVA) was conducted to determine whether differentiated instruction significantly affected students' mathematics achievement after controlling for their initial achievement scores. Pretest scores were included as a covariate, while instructional strategy and gender were entered as factors in the model. The results of the ANCOVA, including the main effects of instructional strategy and gender and the strategy × gender interaction, are presented in Table 3.

Table 3

Summary of Analysis of Covariance of mathematics achievement scores by treatment and gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	356.380a	4	89.095	4.879	.001	.163
Intercept	1056.796	1	1056.796	57.871	.000	.367
Pretest (covariate)	10.662	1	10.662	.584	.447	.006
Strategy	249.327	1	249.327	13.653	.000	.120
Gender	4.613	1	4.613	.253	.616	.003
Strategy * Gender	32.351	1	32.351	1.772	.186	.017
Error	1826.134	100	18.261			
Total	20956.000	105				
Corrected Total	2182.514	104				

a. R Squared = .163 (Adjusted R Squared = .130)

Table 3 shows a statistically significant difference between the experimental and control groups, $F(1, 100) = 13.653$, $p < .001$, partial $\eta^2 = .120$. The partial η^2 indicates that treatment alone accounted for approximately 12% of the combined effect-and-error variability in achievement scores, a moderate effect. Because $p < .05$, the first null hypothesis was rejected: students who received differentiated instruction achieved significantly higher mathematics scores than those who received conventional instruction. Analysis of Covariance was also used to test Hypothesis Two, which stated that gender has no significant effect on senior secondary students' mathematics achievement under differentiated instruction. As shown in Table 3, the main effect of gender was not statistically significant, $F(1, 100) = .253$, $p = .616$, partial $\eta^2 = .003$. Because $p > .05$, the second null hypothesis was retained: male and female students' mathematics achievement scores did not differ significantly under differentiated instruction, indicating an equitable pattern of achievement across gender.

3.1.5 Treatment–Gender Interaction Effect on Mathematics Achievement

To determine whether the effectiveness of differentiated instruction varied according to students' gender, the interaction between instructional strategy and gender was examined using ANCOVA while controlling for students' pretest achievement scores. This analysis was intended to establish whether male and female students responded differently to differentiated instruction relative to conventional instruction. Accordingly, Hypothesis Three stated that the interaction between treatment and gender has no significant effect on senior secondary students' mathematics achievement.

The results showed that the interaction between instructional strategy and gender was not statistically significant, $F(1, 100) = 1.772$, $p = .186$, partial $\eta^2 = .017$. The small effect size further indicates that the interaction accounted for only a limited proportion of the variance in post-treatment achievement. Therefore, the third null hypothesis was retained, suggesting that the effect of differentiated instruction on mathematics achievement did not significantly differ by gender. This finding indicates that the instructional approach produced comparable achievement effects for male and female students, providing evidence that its effectiveness was not dependent on gender.

3.2 Discussion

The significant main effect of treatment demonstrates that differentiated instruction improved students' mathematics achievement substantially more than conventional teaching. This corroborates earlier Nigerian findings linking learner-centered strategies to stronger content learning (Abiodun & Asanre, 2025) and is consistent with international evidence that carefully implemented differentiation, particularly when systematically tailored to learner needs, produces measurable achievement gains (Bal, 2023; Meutstege et al., 2023) and with findings that differentiated approaches can significantly raise achievement even outside mathematics when implemented with fidelity (Adeniran et al., 2025). The result also aligns with reviews indicating that DI's benefit derives from its capacity to accommodate variability in prior knowledge, learning style, and cognitive capacity by offering multiple pathways into the same mathematical content, ensuring that a wider range of students can engage meaningfully with the material (Smale-Jacobse et al., 2019; Deunk et al., 2018).

The non-significant main effect of gender, and the non-significant treatment-by-gender interaction, indicate that both male and female students benefited from differentiated instruction to a statistically similar degree. This finding contributes a more encouraging data point to a gender literature that remains genuinely divided: some large-scale international analyses continue to report a gap favoring boys once assessment bias toward reading skills is controlled for (Lu et al., 2023), while other work traces widening gaps in secondary school specifically to motivational and self-efficacy dynamics that accumulate over time rather than to differences in underlying ability (Ellison & Swanson, 2023; Bohrnstedt et al., 2024), and school-effectiveness studies suggest the gap itself is context-dependent rather than fixed (Oregui-González et al., 2024). The present result is consistent with the interpretation that a well-implemented differentiation strategy, one that deliberately varies task readiness, interest, and product for every student, can narrow or neutralize the conditions under which such gaps typically emerge, without needing to target gender directly as an intervention variable (Dogbe & Ali, 2025).

Reading these results through the documentational, resource-oriented lens described in Section 2.5 (Matranga & Silverman, 2022) makes it possible to separate what is portable to distance and digital mathematics education from what is not. The classification of the differentiation resources used in this study is summarized in Table 4.

Table 4

Portability of the differentiated instruction components used in this study to distance and digital mathematics learning

DI Component (Face-to-Face)	Distance/Digital Equivalent	Portability
Readiness — tiered mathematics tasks	Adaptive item banks / branching digital modules that route students by demonstrated readiness	High — directly transferable
Interest — student-selected task variants	Student-selected asynchronous resource menus (choice boards)	High — directly transferable
Product — varied assessment formats (oral, written, project)	Asynchronous multi-format submission (video explanation, interactive worksheet, written proof)	High — directly transferable
Learning profile — multiple representations of content	Multi-format digital content (video, interactive simulation, text)	Moderate — requires redesign of materials
Process — flexible, teacher-observed small-group work	Structured, pre-planned grouping protocols informed by diagnostic/pretest data	Low — requires substitution, not direct transfer

Three components of the intervention rested on resources that are not classroom-specific and were coded as directly transferable: tiered tasks calibrated to readiness, which can be operationalized as adaptive item banks or branching digital modules that route students to appropriately challenging problems, as demonstrated in early-grade

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adaptive mathematics platforms (Bang et al., 2023); varied assessment products, which map onto asynchronous submission formats already used in distance mathematics courses; and interest-based task choice, which does not depend on the teacher being physically present with the student. Learning-profile differentiation through multiple representations was coded as moderately portable, since it requires redesigning static materials into multi-format digital content but does not depend on real-time interaction. Flexible small-group work, by contrast, was coded as the least portable component: in the present study it depended on the teacher's real-time, face-to-face observation of student engagement to reconstitute groups mid-lesson. Studies of teachers attempting this specific form of differentiation in remote and hybrid settings report that it is precisely this responsive, in-the-moment regrouping that breaks down first, because the digital resources available to teachers (asynchronous forums, static breakout assignments) do not support the same immediacy of feedback (Matranga & Silverman, 2022). This suggests that a distance or digital redesign of the present intervention would need to substitute structured, pre-planned grouping protocols, informed by pretest or diagnostic data rather than in-lesson observation, for the flexible grouping used here, and that teachers implementing such a redesign would themselves require the specific digital pedagogical competence to interpret adaptive-platform data and act on it (Ndia et al., 2025; Estaiteyeh & DeCoito, 2023a), a competence that is not automatically present simply because a teacher can differentiate effectively face-to-face (Hayden et al., 2024; Cody et al., 2023; Estaiteyeh & DeCoito, 2023b).

This reframing does not change what was found in the Ijebu classrooms; it changes what the finding is used for. Rather than treating the achievement gain and the gender-neutral pattern as conclusions specific to one quasi-experiment, they function here, together with the resource classification in Table 4, as an evidence base for a specific design claim: readiness-, interest-, and product-based differentiation is likely to transfer to distance and digital mathematics courses with moderate redesign effort, while process-based differentiation through flexible, teacher-observed grouping is the component most likely to require substitution with structured digital protocols rather than direct replication.

4. Conclusion

This study found that differentiated instruction produced significantly greater gains in senior secondary students' mathematics achievement than conventional lecture-based teaching, with no significant effect of gender and no significant treatment-by-gender interaction. These results support differentiated instruction as an effective and gender-equitable approach to mathematics teaching within the conventional Nigerian secondary classroom, consistent with a learner-centered pedagogy that offers multiple pathways to mathematical understanding.

Beyond this classroom-based conclusion, the study offers a specific, evidence-grounded resource for the design of distance and digital mathematics learning. As summarized in Table 4, curriculum designers and course developers working in distance or hybrid mathematics programs can draw directly on the validated readiness-, interest-, and product-based differentiation strategies used here when building adaptive item banks, branching digital modules, and varied asynchronous assessment formats. At the same time, designers should not assume that flexible, teacher-observed grouping will transfer without substitution; distance and digital implementations of this intervention would need structured, data-informed grouping protocols in place of real-time regrouping, and teacher professional development that builds specifically digital pedagogical competence for interpreting and acting on differentiation-relevant data, rather than assuming that face-to-face differentiation skill transfers automatically to a digital environment.

The study has limitations. The sample, drawn from two schools in the Ijebu Education Zone, may not represent the broader population of Ogun State or Nigeria, and the quasi-experimental design, using intact classes, is potentially subject to selection bias from pre-existing group differences. The resource-portability classification in Table 4 is itself based on document analysis rather than direct implementation in a distance setting; because the intervention was delivered face-to-face, the transferability claims made above are analytical rather than empirically tested. Future research should implement and evaluate a distance or hybrid redesign of this same differentiation strategy directly, substituting the flexible-grouping component with the structured digital protocol proposed here, to test whether the achievement and gender-equity patterns reported in this study hold under distance delivery.

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Author Contributions
Taiwo Abiodun conceived and designed the study, supervised the research process, and validated the final manuscript.
Abimbola Ismail Arigbabu collected the data and carried out the statistical analysis.
Lawrence Adesola Adebiyi assisted with data collection and edited the manuscript. All authors read and approved the final version of the manuscript.

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The authors declare no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

AI Use Disclosure

During the preparation of this manuscript, the authors used Claude (Anthropic) to assist with language editing and typographical corrections, as well as with literature searching, reference identification, and citation formatting. All AI-assisted content was reviewed and verified by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript. No AI tool is listed as an author or co-author.

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