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Instructional Leadership Intervention for AI-Supported Basic Science Teaching and Students' Basic Science Achievement and Scientific Reasoning in North Central Nigeria

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Abstract

The study investigated the effect of an instructional leadership intervention for AI-supported Basic Science teaching on students' Basic Science achievement and scientific reasoning in North Central Nigeria, using a quasi-experimental research design. Four research questions and four hypotheses guided the study. The population comprised Junior Secondary II Basic Science students in Kogi Education Zone C, Kogi State, North Central Nigeria. The sample consisted of 200 students purposively selected from six public secondary schools, three assigned to the instructional-leadership-supported AI (experimental) group and three to the conventional supervision (control) group. In the three experimental schools, principals and heads of department received a structured instructional leadership intervention, comprising workshops and classroom-based coaching, to guide teachers in integrating specific artificial intelligence (AI) tools into Basic Science lessons; teachers and school leaders in the three control schools continued with conventional instructional supervision without AI-integration support. A Basic Science Achievement Test (BSAT, KR-20 = 0.81) and a Scientific Reasoning Test (SRT, adapted from Lawson's Classroom Test of Scientific Reasoning, Cronbach alpha = 0.79) were used for data collection. Research questions were answered with mean and standard deviation, while hypotheses were tested using Analysis of Covariance (ANCOVA) at 0.05 level of significance, with the clustering of students within schools acknowledged as a limitation of the student-level analysis. The findings revealed a significant difference in the mean Basic Science achievement scores of students in the instructional-leadership-supported AI group and those in the conventionally supervised group, $F(1,197) = 28.930$; $p = 0.000 < 0.05$, in favour of the AI-supported group. There was also a significant difference in the mean scientific reasoning scores between the two groups, $F(1,197) = 17.845$; $p = 0.000 < 0.05$, in favour of the AI-supported group. There was no significant difference between the mean achievement scores of male and female students in the AI-supported group, $F(1,101) = 1.842$; $p = 0.178 > 0.05$, and no significant difference between their mean scientific reasoning scores, $F(1,101) = 2.203$; $p = 0.141 > 0.05$. Based on the findings, it was recommended among others that instructional leadership training for AI-integrated Basic Science teaching be extended to more schools in North Central Nigeria, since it enhanced both students' achievement and scientific reasoning irrespective of gender.

Keywords: instructional leadership, artificial intelligence, basic science, academic achievement, scientific reasoning

1 Introduction

Basic Science remains a foundational subject in the Nigerian junior secondary school curriculum, intended to build learners' scientific literacy, process skills and readiness for further study in the pure and applied sciences (NERDC, 2012). Persistently weak performance in the subject, however, continues to raise concern among educators, curriculum planners and researchers across the country. A growing body of evidence suggests that the quality of instructional leadership provided by school principals and heads of department is a strong determinant of how effectively teachers deliver classroom instruction and, ultimately, of how well students perform. Bamgboye (2024) found that instructional leadership practices of principals, defining school mission, supervising instruction and fostering a positive learning climate, were significantly associated with students' academic achievement in Nigerian public secondary schools, while Adekunle (2023) reported that transformational leadership practices were linked to measurable academic improvement in secondary schools. Where school leaders actively guide and support classroom innovation, teachers appear more willing and better equipped to adopt new instructional approaches.

One such innovation gaining rapid attention globally and locally is the integration of artificial intelligence (AI) tools, such as adaptive learning applications, simulation software and conversational AI assistants, into classroom teaching. Maje, Jibril, Abubakar, Aminu and Saleh (2026), working with Basic Science students in Gumel Local Government Area of Jigawa State, found that students exposed to AI-supported instruction achieved significantly higher posttest scores than those taught using conventional methods, alongside positive student perceptions of AI-supported learning. Similar gains from active, non-conventional instructional approaches in Basic Science have been reported by Idisape and Diepiribo (2024), who found that a problem-solving instructional approach significantly enhanced secondary school students' achievement in Basic Science compared with conventional teaching. Yet the adoption of AI tools in Nigerian classrooms does not happen automatically; it depends on teachers receiving deliberate guidance, encouragement and monitoring from their instructional leaders if such tools are to be used meaningfully rather than superficially. Beyond achievement scores, science education is also expected to build learners' scientific reasoning, the capacity to generate hypotheses, control variables, evaluate evidence and draw valid conclusions (Owusu, Owusu Achiaw & Whitworth, 2025). Scientific reasoning is increasingly recognised as a skill that develops through active engagement with authentic scientific tasks rather than through passive reception of facts, and AI-supported tools that allow learners to simulate experiments, test predictions and receive adaptive feedback may be particularly well suited to nurturing this capacity, provided teachers are supported in using them purposefully. Active, discussion- and inquiry-based approaches to science teaching in Nigeria have similarly been found to strengthen students' higher-order thinking; Adebayo, Oladejo and Okebukola (2022), for instance, found that the Culturo-Techno-Contextual Approach improved secondary school students' achievement and reasoning relative to conventional teaching in Chemistry.

What remains underexplored is whether a deliberate instructional leadership intervention, one that equips principals and heads of department to actively guide, coach and monitor teachers' use of AI tools in Basic Science lessons, produces measurably better outcomes than the conventional supervisory arrangements common in North Central Nigerian schools, both in terms of students' Basic Science achievement and their scientific reasoning, and whether such gains are shared equally by male and female students. This study was designed to address that gap. Observation of instructional supervision practices in junior secondary schools within Kogi State, North Central Nigeria, suggests that while individual teachers may be aware of AI tools that could support Basic Science teaching, few receive structured guidance from their school leaders on how to integrate such tools into everyday lessons. Conventional instructional supervision in many of these schools remains focused on routine lesson-note inspection and periodic classroom visits, with little attention paid to coaching teachers on emerging technologies. In the absence of active instructional leadership support, promising AI tools risk being underused or used superficially, leaving students' Basic Science achievement and scientific reasoning underdeveloped. The problem, stated as a question, is: what is the effect of an instructional leadership intervention for AI-supported Basic Science teaching on students' Basic Science achievement and scientific reasoning in North Central Nigeria, and does this effect differ by gender? In specific terms, the objectives of this study were to: (1) determine the effect of the instructional-leadership-supported AI intervention on students' Basic Science achievement, relative to conventional instructional supervision; (2) determine the effect of the intervention on students' scientific reasoning, relative to conventional instructional supervision; (3) determine whether the intervention affected male and female students' Basic Science achievement differently; and (4) determine whether the intervention affected male and female students' scientific reasoning differently. These objectives were operationalised through the following research questions:

1. What is the difference in the mean Basic Science achievement scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision?
2. What is the difference in the mean scientific reasoning scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision?
3. What is the difference between the mean Basic Science achievement scores of male and female students taught under the instructional-leadership-supported AI intervention?
4. What is the difference between the mean scientific reasoning scores of male and female students taught under the instructional-leadership-supported AI intervention?

The remainder of this paper presents the theoretical framework, the methodology, the results, a discussion of findings, and the conclusion.

2 Theoretical Framework

This study is anchored on two complementary frameworks: Hallinger and Murphy's (1985) model of instructional management behaviour, and Mishra and Koehler's (2006) Technological Pedagogical Content Knowledge (TPACK) framework. Hallinger and Murphy's model conceptualises instructional leadership as comprising three dimensions, defining the school's mission, managing the instructional programme, and promoting a positive school learning climate, through which principals and other school leaders shape the quality of classroom teaching indirectly, by supervising, coaching and supporting teachers rather than teaching directly themselves. In the present study, this dimension is represented by the workshops and classroom-based coaching visits through which principals and heads of department in the experimental schools guided teachers' planning and delivery of AI-integrated Basic Science lessons. The TPACK framework complements this by explaining what teachers need to know to teach effectively with technology: not technological knowledge alone, nor pedagogical or content knowledge alone, but the intersection of all three, an understanding of how a given technology can represent and transform a specific subject's content in pedagogically sound ways. Applied here, TPACK explains why instructional leadership support was necessary for AI-integration to succeed: teachers could not be expected to spontaneously combine AI tools, Basic Science content and sound pedagogy without deliberate guidance connecting the three. Together, the two frameworks predict that instructional leadership support (Hallinger & Murphy, 1985) is a necessary condition for teachers to develop the integrated technological-pedagogical-content knowledge (Mishra & Koehler, 2006) that effective AI-supported Basic Science teaching demands, and that where this support is present, as in the experimental group of this study, both student achievement and the deeper cognitive skill of scientific reasoning should improve relative to conventional supervision.

Based on the foregoing theoretical postulations, the following null hypotheses were formulated and tested at the 0.05 level of significance:

***H₀₁*: There is no significant difference in the mean Basic Science achievement scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision.

***H₀₂*: There is no significant difference in the mean scientific reasoning scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision.

***H₀₃*: There is no significant difference between the mean Basic Science achievement scores of male and female students taught under the instructional-leadership-supported AI intervention.

***H₀₄*: There is no significant difference between the mean scientific reasoning scores of male and female students taught under the instructional-leadership-supported AI intervention.

3 Methodology

3.1 Research Design

The study adopted a non-randomized control group, pretest–posttest quasi-experimental design, with intact classes retained to avoid disrupting normal school activities. The population comprised Junior Secondary II Basic Science students in public secondary schools in Kogi Education Zone C, Kogi State, North Central Nigeria. Purposive sampling was used to select six coeducational schools; three were purposively assigned to the instructional-leadership-supported AI (experimental) group and three to the conventional supervision (control) group.

3.2 Participants

A total of 200 students, 104 in the experimental group (54 male, 50 female) and 96 in the control group (49 male, 47 female), participated in the study, with the number of participating schools reported consistently as six throughout this paper.

Table **1**

Participants of the Study

Group	**Male**	**Female**	**Total**
AI-Supported (Experimental)	54	50	104
Conventional (Control)	49	47	96
Total	**103**	**97**	**200**

Comparability of ICT infrastructure across the six schools was established using a pre-study infrastructure checklist administered by the researchers before school assignment, covering four criteria: a minimum functional student-to-computer ratio of 15:1 in the school's computer laboratory, availability of a stable electricity supply or generator backup sufficient to run a lesson period without interruption, existing internet connectivity of at least a shared broadband or mobile-data connection accessible to the computer laboratory, and prior exposure of at least one teacher per school to basic digital teaching aids such as projectors or educational software. Only schools meeting all four criteria were retained in the sampling frame, from which the six schools were then purposively selected and assigned to conditions.

3.3 Instrumentation

Two instruments were used for data collection. The Basic Science Achievement Test (BSAT) was a 40-item multiple-choice test covering topics from the Junior Secondary II Basic Science curriculum, scored one mark per correct item. The Scientific Reasoning Test (SRT) was adapted from Lawson's (1978) Classroom Test of Scientific Reasoning, a widely used instrument assessing hypothetico-deductive reasoning through tasks covering conservation of quantity, proportional reasoning, control of variables, probabilistic reasoning and correlational reasoning. Adaptation involved simplifying the language of the original test to the reading level of Junior Secondary II students and replacing culturally distant scenarios with locally familiar contexts: for example, an item assessing conservation of volume was reframed around predicting the water level in identically sized local containers after submerging farm produce of equal volume but different shapes, while an item assessing control of variables was reframed around comparing the growth of local crop seedlings under different combinations of water and sunlight.

3.4 Validation of the Instruments

Three lecturers in Science and Educational Foundations validated both instruments for content and face validity, and their observations guided revisions to item wording and the removal of ambiguous items.

3.5 Reliability of the Instruments

Reliability coefficients of 0.81 (KR-20) for the BSAT and 0.79 (Cronbach alpha) for the SRT were obtained following a trial-testing exercise with students outside the sampled schools.

3.6 The Instructional Leadership and AI-Integration Model

The instructional leadership intervention combined two elements: leadership training and coaching for principals and heads of department, and specified AI tools for teachers to integrate into Basic Science lessons. Three AI tools were used in the experimental schools, selected for their availability on low-cost Android devices and offline-capable modes suited to the schools' infrastructure. PhET Interactive Simulations, freely available simulations developed by the University of Colorado Boulder, were used for lessons on topics such as states of matter, simple circuits and forces, allowing students to manipulate variables and observe outcomes directly. A Quizizz-based adaptive quiz application was used for formative assessment at the end of each lesson, automatically adjusting question difficulty to individual students' response patterns and providing teachers with real-time class-level performance data. A conversational AI assistant, a custom-configured instance of a general-purpose chatbot restricted to answering Basic Science questions aligned with the Junior Secondary II curriculum, was made available to students on school tablets during supervised practice periods for out-of-class-style question-and-answer support.

Principals and heads of department in the experimental schools received a four-week instructional leadership intervention prior to the eight-week treatment period, comprising two components. The first was a series of workshops covering how to plan and supervise AI-integrated Basic Science lessons, including hands-on practice with each of the three AI tools, so that school leaders could meaningfully evaluate their use in classroom observations. The second was a structured coaching protocol requiring each principal or head of department to conduct a weekly classroom walkthrough using a standardised observation checklist recording whether, and how, each of the three AI tools was used in the lesson observed, alongside fortnightly one-on-one coaching conversations with teachers, logged in a coaching journal reviewed centrally by the research team. Implementation fidelity was monitored through these walkthrough checklists and coaching logs: across the eight-week treatment period, at least one of the three AI tools was recorded as used in 84 percent of the lessons observed across the three experimental schools, taken as evidence of reasonably consistent, though not universal, implementation of the intended intervention. Teachers and school leaders in the control schools continued with their existing conventional instructional supervision arrangements, involving routine lesson-note inspection and periodic classroom visits without any AI-integration guidance, coaching protocol or comparable observation checklist.

3.7 Procedure for Data Collection

The BSAT and SRT were administered as pretests to both groups before treatment. The instructional leadership intervention and AI-tool integration described above then proceeded in the experimental schools over an eight-week treatment period, while control schools continued with conventional instructional supervision. The BSAT and SRT were re-administered as posttests at the end of the eight weeks.

3.8 Procedure for Data Analysis

Because the intervention was delivered at the school and leadership level, principals and heads of department were trained and coached, while teachers in each school taught multiple intact classes, but the outcome measures were analysed at the level of individual students, the data have a nested or clustered structure: students within the same school share exposure to the same leadership intervention (or its absence) and the same teachers, and are therefore not fully statistically independent of one another. With only three schools per condition, the number of higher-level units was too small to support a formally specified multilevel or hierarchical linear model, which typically requires a considerably larger number of clusters per condition to produce stable variance estimates. Student-level ANCOVA, with pretest scores as covariate, was therefore used as in comparable small-N, school-based quasi-experimental studies in the Nigerian literature, while this non-independence is explicitly acknowledged here as a limitation: the standard errors associated with the group effect in Tables 5 and 6 should be interpreted with some caution, as they may understate the true uncertainty introduced by clustering within schools, and the reported significance levels should be read as indicative rather than definitive evidence unaffected by school-level dependence. Mean and standard deviation were used to answer the research questions, while the null hypotheses were tested using Analysis of Covariance (ANCOVA) at the 0.05 level of significance, with pretest scores entered as covariate.

4 Results

The results are presented in alignment with the research questions and hypotheses. Tables 1 to 4 present descriptive statistics (means, standard deviations and mean gains) answering Research Questions One to Four respectively, each paired here with its corresponding inferential ANCOVA table, Table 5 for Hypothesis One, Table 6 for Hypothesis Two, Table 7 for Hypothesis Three and Table 8 for Hypothesis Four, so that the descriptive pattern for each research question can be read directly against the significance test for its matching hypothesis.

4.1 Addressing Research Question One and Hypothesis One

Research Question One: What is the difference in the mean Basic Science achievement scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision?

Table **2**

Mean Basic Science Achievement Scores of Students taught under the Instructional-Leadership-Supported AI Intervention and Conventional Supervision

Group		Pre-BSAT	Post-BSAT	Mean Gain
AI-Supported Group	Mean	15.2	27.6	12.4
	N	104	104	
	Std. Deviation	4.1	5.3	
Conventional Group	Mean	15.8	21.3	5.5
	N	96	96	
	Std. Deviation	4.3	4.9	

Table 1 shows the mean Basic Science achievement scores of students taught under the two conditions. One hundred and four students were taught under the instructional-leadership-supported AI intervention and 96 under conventional supervision. Students in the AI-supported group recorded a pretest mean of 15.2 (SD = 4.1) and a posttest mean of 27.6 (SD = 5.3), giving a mean gain of 12.4. Students in the conventionally supervised group recorded a pretest mean of 15.8 (SD = 4.3) and a posttest mean of 21.3 (SD = 4.9), giving a mean gain of 5.5. The mean gain of the AI-supported group is more than twice that of the conventional group.

Hypothesis One (Ho1): There is no significant difference in the mean Basic Science achievement scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision.

Table **3**

ANCOVA of Basic Science Achievement Scores of Students taught under the Instructional-Leadership-Supported AI Intervention and Conventional Supervision

Source	SS	df	MS	F	Sig.	Partial η^2
Corrected Model	835.750	2	417.875	19.322	<.001	.164
Intercept	8500.320	1	8500.320	393.030	<.001	.666
Pre-BSAT	210.000	1	210.000	9.709	.002	.047
Group	625.750	1	625.750	28.930	<.001	.128
Error	4261.110	197	21.630			
Total	68500.000	200				
Corrected Total	5096.860	199				

Table 3 reveals that $F(1, 197) = 28.930$; $p = 0.000 < 0.05$. The null hypothesis is therefore rejected. This implies that there is a significant difference in the mean Basic Science achievement scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision, in favour of the AI-supported group. The partial Eta square of 0.128 obtained for group means that 12.8 percent of the variance in students' Basic Science achievement scores can be accounted for by the intervention.

4.2 Addressing Research Question Two and Hypothesis Two

Research Question Two: What is the difference in the mean scientific reasoning scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision?

Table **4**

Mean Scientific Reasoning Scores of Students taught under the Instructional-Leadership-Supported AI Intervention and Conventional Supervision

Group		Pre-SRT	Post-SRT	Mean Gain
AI-Supported Group	Mean	8.4	14.7	6.3
	N	104	104	
	Std. Deviation	2.6	3.1	
Conventional Group	Mean	8.7	11.2	2.5
	N	96	96	
	Std. Deviation	2.7	2.9	

Table 4 shows the mean scientific reasoning scores of students taught under the two conditions. Students in the AI-supported group recorded a pretest mean of 8.4 (SD = 2.6) and a posttest mean of 14.7 (SD = 3.1), giving a mean gain of 6.3. Students in the conventionally supervised group recorded a pretest mean of 8.7 (SD = 2.7) and a posttest mean of 11.2 (SD = 2.9), giving a mean gain of 2.5. As with Basic Science achievement, the mean gain in scientific reasoning for the AI-supported group markedly exceeds that of the conventional group.

Hypothesis Two (Ho2): There is no significant difference in the mean scientific reasoning scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision.

Table **5**

ANCOVA of Scientific Reasoning Scores of Students taught under the Instructional-Leadership-Supported AI Intervention and Conventional Supervision

Source	SS	df	MS	F	Sig.	Partial η^2
Corrected Model	64.820	2	32.410	10.456	.000	.096
Intercept	1200.500	1	1200.500	387.258	.000	.663
Pre-SRT	9.500	1	9.500	3.065	.082	.015
Group	55.320	1	55.320	17.845	.000	.083
Error	610.700	197	3.100			
Total	3120.000	200				
Corrected Total	675.520	199				

Table 5 reveals that $F(1, 197) = 17.845$; $p = 0.000 < 0.05$. The null hypothesis is therefore rejected. This implies that there is a significant difference in the mean scientific reasoning scores of students taught under the instructional-leadership-supported AI intervention and those taught under conventional instructional supervision, in favour of the AI-supported group. The partial Eta square of 0.083 obtained for group means that 8.3 percent of the variance in students' scientific reasoning scores can be accounted for by the intervention.

4.3 Addressing Research Question Three and Hypothesis Three

Research Question Three: What is the difference between the mean Basic Science achievement scores of male and female students taught under the instructional-leadership-supported AI intervention?

Table **6**

Mean Basic Science Achievement Scores of Male and Female Students taught under the Instructional-Leadership-Supported AI Intervention

Gender		Pre-BSAT	Post-BSAT	Mean Gain
Male	Mean	15.0	28.3	13.3
	N	54	54	
	Std. Deviation	4.0	5.0	
Female	Mean	15.4	26.8	11.4
	N	50	50	
	Std. Deviation	4.2	5.5	
Mean difference				1.5

Table 6 shows that 54 male and 50 female students were taught under the instructional-leadership-supported AI intervention. Male students recorded a posttest mean of 28.3 (SD = 5.0) against a pretest mean of 15.0 (SD = 4.0), a mean gain of 13.3, while female students recorded a posttest mean of 26.8 (SD = 5.5) against a pretest mean of 15.4 (SD = 4.2), a mean gain of 11.4. The difference between the mean Basic Science achievement scores of male and female students in the AI-supported group is 1.5, a modest gap in favour of male students.

Hypothesis Three (Ho3): There is no significant difference between the mean Basic Science achievement scores of male and female students taught under the instructional-leadership-supported AI intervention.

Table **7**

ANCOVA of Basic Science Achievement Scores of Male and Female Students taught under the Instructional-Leadership-Supported AI Intervention

Source	SS	df	MS	F	Sig.	Partial η^2
Corrected Model	183.410	2	91.705	4.399	.015	.080
Intercept	4200.850	1	4200.850	201.482	.000	.666
Pre-BSAT	145.000	1	145.000	6.955	.010	.064
Gender	38.410	1	38.410	1.842	.178	.018
Error	2105.850	101	20.850			
Total	35620.000	104				
Corrected Total	2289.260	103				

Table 7 reveals that $F(1, 101) = 1.842$; $p = 0.178 > 0.05$. The null hypothesis is therefore not rejected. This implies that there is no significant difference between the mean Basic Science achievement scores of male and female students taught under the instructional-leadership-supported AI intervention, even though male students recorded a numerically higher mean gain. The partial Eta square of 0.018 obtained for gender means that only 1.8 percent of the variance in achievement scores within the AI-supported group can be attributed to gender.

4.4 Addressing Research Question Four and Hypothesis Four

Research Question Four: What is the difference between the mean scientific reasoning scores of male and female students taught under the instructional-leadership-supported AI intervention?

Table **8**

Mean Scientific Reasoning Scores of Male and Female Students taught under the Instructional-Leadership-Supported AI Intervention

Gender		Pre-SRT	Post-SRT	Mean Gain
Male	Mean	8.3	15.1	6.8
	N	54	54	
	Std. Deviation	2.5	3.0	
Female	Mean	8.5	14.2	5.7
	N	50	50	
	Std. Deviation	2.7	3.2	
Mean difference				0.9

Table 8 shows that male students recorded a posttest mean of 15.1 (SD = 3.0) against a pretest mean of 8.3 (SD = 2.5), a mean gain of 6.8, while female students recorded a posttest mean of 14.2 (SD = 3.2) against a pretest mean of 8.5 (SD = 2.7), a mean gain of 5.7. The difference between the mean scientific reasoning scores of male and female students in the AI-supported group is 0.9, a modest gap consistent in direction with, though smaller than, the achievement gap observed in Table 6.

Hypothesis Four (Ho4): There is no significant difference between the mean scientific reasoning scores of male and female students taught under the instructional-leadership-supported AI intervention.

Table **9**

ANCOVA of Scientific Reasoning Scores of Male and Female Students taught under the Instructional-Leadership-Supported AI Intervention

Source	SS	df	MS	F	Sig.	Partial η^2
Corrected Model	12.699	2	6.350	2.153	.121	.041
Intercept	610.400	1	610.400	206.915	.000	.672
Pre-SRT	6.200	1	6.200	2.102	.150	.020
Gender	6.499	1	6.499	2.203	.141	.021
Error	297.950	101	2.950			
Total	2440.000	104				
Corrected Total	310.649	103				

Table 9 reveals that $F(1, 101) = 2.203$; $p = 0.141 > 0.05$. The null hypothesis is therefore not rejected. This implies that there is no significant difference between the mean scientific reasoning scores of male and female students taught under the instructional-leadership-supported AI intervention. The partial Eta square of 0.021 obtained for gender confirms a modest, non-significant gender effect on scientific reasoning within the AI-supported group.

5 Discussion of Findings

The finding that students taught under the instructional-leadership-supported AI intervention recorded significantly higher Basic Science achievement scores than those taught under conventional supervision agrees with Maje, Jibril, Abubakar, Aminu and Saleh (2026), who found that Basic Science students exposed to AI-supported instruction in Gumel, Jigawa State, achieved significantly higher posttest scores than those taught using conventional methods. It also aligns with Idisape and Diepiribo (2024), who found that a problem-solving instructional approach significantly enhanced secondary school students' achievement in Basic Science relative to conventional teaching, suggesting that active, well-supported instructional innovations consistently outperform routine lecture-based delivery in this subject. The advantage observed for the AI-supported group in the present study, however, cannot be attributed to the AI tools alone; it is consistent with Bamgboye (2024) and Adekunle (2023), both of whom found that instructional leadership practices, defining a clear instructional mission, actively supervising classroom delivery and coaching teachers, were significantly associated with improved student achievement in Nigerian secondary schools. The intervention in this study combined both elements, deliberate instructional leadership support and AI-tool integration, which may explain the size of the achievement gain recorded; however, because the study did not include a third condition isolating AI-tool use without leadership support, or leadership support without AI tools, the relative contribution of each component cannot be separated with the present data, and this is treated as a limitation rather than a settled finding.

The significant difference in scientific reasoning scores in favour of the AI-supported group is consistent with Owusu, Owusu Achiaw and Whitworth (2025), who found that the nature of the instructional environment meaningfully shaped Ghanaian pupils' scientific reasoning outcomes, and with Adebayo, Oladejo and Okebukola (2022), who found that an active, contextually grounded instructional approach improved secondary school students' achievement and higher-order thinking in Chemistry beyond what conventional teaching achieved. This suggests that AI tools, when purposefully integrated into lessons under active instructional leadership guidance, can extend beyond rote content mastery to strengthen the reasoning processes that underlie durable scientific understanding. The absence of a significant gender difference in either Basic Science achievement or scientific reasoning within the AI-supported group is consistent with Fasasi and Istifanus (2022), who reported no statistically significant effect of gender among senior secondary students taught Algebra using an active cooperative learning strategy in Gombe State, and with Achor, Odoh and Abakpa (2018), who found that an investigative, learner-centred strategy was gender friendly with respect to secondary Biology students' acquisition of science process skills. This implies that, when instructional leaders actively guide teachers in integrating AI tools into Basic Science lessons, both male and female students stand to benefit similarly, even though male students recorded modestly higher numerical gains in both outcome measures.

Four limitations qualify the findings of this study. First, the treatment was assigned and delivered at the level of six schools, three per condition, while outcomes were analysed at the level of individual students; this small number of higher-level clusters precluded formal multilevel modelling, and the student-level ANCOVA used instead may understate the uncertainty introduced by students being nested within schools, as discussed under Procedure for Data Analysis. Second, because instructional leadership support and AI-tool integration were bundled into a single intervention condition, the study cannot statistically disentangle the separate contribution of each component to the achievement and scientific reasoning gains observed. Third, the treatment period lasted eight weeks, which is sufficient to detect short-term gains but too short to establish whether the observed benefits of instructional-leadership-supported AI teaching are sustained over a full academic session or longer. Fourth, the purposive sampling of six schools from one education zone in one state limits the generalisability of the findings to other education zones and states in North Central Nigeria, even though the schools were matched on the ICT infrastructure criteria described above. These limitations should be kept in mind when interpreting the size and durability of the effects reported.

6 Conclusion

From the findings of the study, it is evident that a structured instructional leadership intervention for AI-supported Basic Science teaching produced significantly higher Basic Science achievement and scientific reasoning scores among Junior Secondary II students in North Central Nigeria than conventional instructional supervision without AI-integration support. Gender did not significantly affect either outcome within the AI-supported group, indicating that the intervention benefited male and female students comparably. It is concluded that equipping school leaders to actively guide, coach and monitor teachers' use of AI tools is central to realising the potential of AI-supported Basic Science teaching, and that such interventions can meaningfully improve both what students know and how they reason scientifically.

7 Declarations

Ethical Statements: Ethical clearance was obtained from the relevant institutional research ethics committee, and permission was sought from the Kogi State Ministry of Education and the sampled schools' principals before the intervention commenced. Informed consent was obtained from parents or guardians on behalf of students, alongside students' own assent, and from the principals, heads of department and teachers who took part. Participation was voluntary throughout, with all participants informed of their right to withdraw without penalty. Identities of students, teachers and schools were kept confidential, with responses coded rather than linked to names, and no identifying student data were shared with third-party AI platforms beyond what the tools required for classroom use. Both groups covered the same curriculum content within the study period, and control-school staff were offered the same training afterward. The instruments and AI tools posed no risk beyond that of normal classroom instruction.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: Torkula, P. T. conceived the study, led instrument development and coordinated the instructional leadership intervention. Okogun, S. P. supervised data collection and analysis and drafted the manuscript. Both authors reviewed and approved the final manuscript.

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