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Effects of a Language Proficiency-Based Instructional Strategy on Academic Achievement of Private University STEM Students in Circular Measures in Oyo State, Nigeria

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STEM students at Nigerian private universities frequently struggle with circular measures, defaulting to rote memorisation of formulae rather than developing the conceptual understanding required for genuine problem-solving. This challenge is compounded by limited proficiency in English, the medium of instruction. The present study examined the effect of a language proficiency-based instructional strategy (LPS) on the academic achievement of private university STEM students in circular measures in Oyo State, Nigeria. A quasi-experimental pre-test/post-test design incorporated one experimental group and one control group from two private universities. Purposive and multistage sampling yielded 120 undergraduate 200-level STEM students (60 per institution). The Circular Measures Achievement Test (CMAT; 30 items; KR-20 = 0.87) served as the primary instrument. An a priori power analysis (Cohen's $f = 0.40$, $\alpha = 0.05$, power $= 0.80$) confirmed adequacy of the sample. Data were analysed using Analysis of Covariance (ANCOVA; $df = 1, 117$) with pre-test scores as the covariate. Results indicated a statistically significant main effect of the LPS on post-test achievement, $F(1, 117) = 336.84$, $p < 0.001$, $\eta^2 p = 0.74$. LPS students achieved a substantially higher adjusted mean ($M = 25.37/30$; 84.6%) compared with the conventional group ($M = 18.37/30$; 61.2%). The treatment effect was consistent across students with low, average, and high baseline English proficiency. Findings are interpreted through Vygotsky's sociocultural theory, emphasising the Zone of Proximal Development and language as the primary scaffolding tool in technical learning. Recommendations are offered for classroom practice, teacher training, curriculum policy, and future research.

Keywords: academic achievement, circular measures, language proficiency-based instruction, private universities, STEM education, Vygotsky, Zone of Proximal Development

Introduction

Mathematics constitutes a foundational discipline that underpins critical thinking, logical reasoning, and systematic problem-solving across all scientific and technical fields. In Nigeria, Mathematics is a compulsory component of higher education curricula in science-related programmes, including engineering, physics, and the applied sciences. Since the fifteenth century, mathematical knowledge has expanded exponentially, driven by the demands of commerce, agriculture, technology, and scientific discovery, and its role in contemporary society continues to grow as digital transformation reshapes every sector (Eze & Akinfolarin, 2022). Today, mathematical literacy encompassing computational fluency and quantitative reasoning is recognised as a prerequisite for careers in cybersecurity, artificial intelligence, data science, and engineering, and as an essential tool for informed citizenship in a complex global environment (OECD, 2022; The National Academies Press, 2022).

Within the Nigerian higher education context, recent scholarship has identified a cluster of persistent challenges: mathematical anxiety among undergraduates, curriculum misalignment with contemporary disciplinary practice, inequitable access to quality instruction, and the barrier posed by English as the medium of instruction for students whose first language is not English (Oloruntimehin, 2023; Sabra & Tabchi, 2024). These challenges are particularly acute in specialised topics such as circular measures, which require both conceptual clarity and procedural fluency, and where technical vocabulary terms such as radian, arc length, sector area, and angular velocity must be precisely understood before formulae can be meaningfully applied (Johnson, 2021; Adediran & Balogun, 2021).

Circular measures, or radian measure, express angles in terms of arc length in a unit circle. This topic is fundamental to higher-level Mathematics and to applications across physics, engineering, and computer science. Specifically, an angle θ measured in radians is defined as the ratio of the arc length s to the radius r of a circle ($s = r\theta$). Key formulae include arc length $s = r\theta$, sector area $A = \frac{1}{2} r^2\theta$, and small-angle approximations ($\sin \theta \approx \theta$, $\cos \theta \approx 1 - \theta^2/2$, $\tan \theta \approx \theta$ for small θ in radians). Despite this importance, undergraduate STEM students in Nigerian institutions frequently default to memorising these formulae without understanding their derivation or conceptual basis (Bright, Welcome & Arthur, 2024; Adegoke & Oladipo, 2022).

Language proficiency, particularly in English, plays a pivotal role in mathematical learning in settings where English is the medium of instruction. Students must decode problem statements, interpret procedural instructions, and articulate reasoning strategies using the language of the discipline. Research consistently demonstrates that students with stronger English proficiency perform better across academic domains, including Mathematics, because they can more fully engage with instructional materials and assessments (Oyetunde, 2024; Kamasak, Sahan & Rose, 2021). Conversely, insufficient language proficiency creates a dual barrier: students must simultaneously process mathematical content and navigate an unfamiliar linguistic medium (Appalanaidu, Setambah & Ibrahim, 2025; Oguejiofor & Chukwu, 2020).

The theoretical basis for this study is Vygotsky's (1962) sociocultural theory of cognitive development. Vygotsky argued that learning is fundamentally a social and linguistically mediated process, and that higher mental functions develop through interaction with more knowledgeable others within the Zone of Proximal Development (ZPD) the space between what a learner can accomplish independently and what they can achieve with guided support. Language is identified as the primary psychological tool through which thought is organised, meaning is constructed, and knowledge is internalised. In STEM education, this position predicts that explicit attention to the language of disciplinary practice including mathematical vocabulary, sentence structures for procedural reasoning, and genre conventions will reduce cognitive load and enable students to access conceptual content more effectively. The language proficiency-based instructional strategy (LPS) evaluated in this study operationalises Vygotskian scaffolding by providing structured linguistic support alongside mathematical content, progressively withdrawing that support as learners develop competence.

Despite growing awareness of the language–achievement relationship in STEM education, empirical literature specifically examining LPS interventions in undergraduate Mathematics instruction at private Nigerian universities remains sparse. The private university sector in Oyo State has expanded considerably since the liberalisation of higher education in the early 2000s, and these institutions now serve diverse student populations with varying linguistic backgrounds (Afolabi & Olawale, 2021; Olusanya & Adeyemi, 2023). Understanding how language-focused pedagogy affects mathematical achievement in this context has both theoretical and practical significance. The present study was designed to address this gap.

Statement of the Problem

Available institutional records from private universities in Oyo State indicate that between 40% and 60% of 200-level STEM students fail to achieve pass grades in mathematical topics covering circular measures at their initial attempt. This pattern is consistent with national data on undergraduate Mathematics performance in Nigerian universities (Abdullahi, 2020). The dominant instructional approach remains teacher-centred and lecture-based, emphasising formula presentation and worked examples with minimal student participation a method that does not foster the deep conceptual understanding or procedural fluency that circular measures demand.

A critical but underexplored dimension of this challenge is students' insufficient English language proficiency. In a context where instruction is delivered in English but many students' primary language competence lies elsewhere, the linguistic demands of abstract mathematical discourse interpreting problem statements, following multi-step procedural instructions, and articulating reasoning impose a substantial additional burden. The empirical literature on the effect of language proficiency-based instructional strategies on undergraduate STEM achievement in circular measures, within private universities in Oyo State, is limited. This study was therefore designed to examine this effect experimentally.

Purpose of the Study

The primary purpose of this study was to determine the effect of a language proficiency-based instructional strategy on the academic achievement of private university STEM students in circular measures in Oyo State, Nigeria. Specifically, the study pursued three objectives: (i) to examine the effect of LPS on the overall academic achievement of STEM students in circular measures; (ii) to determine whether the effect of the LPS differed by students' baseline English language proficiency level (low, average, high); and (iii) to compare post-test achievement outcomes between students taught using the LPS and those taught using conventional instruction, after controlling for pre-test scores.

Research Hypotheses

H_{01}: There will be no statistically significant effect of the language proficiency-based instructional strategy on the academic achievement of private university STEM students in circular measures in Oyo State, after controlling for pre-test scores.

H_{02}: There will be no statistically significant difference in the effect of the language proficiency-based instructional strategy on academic achievement across students with low, average, and high baseline English language proficiency levels.

Methodology

Research Design

This study adopted a quasi-experimental pre-test/post-test non-equivalent control group design. This design is appropriate when intact groups cannot be randomly assigned to conditions, as is typical in university-based educational research (Campbell & Stanley, 1966). One intact class from each of two private universities was assigned to either the experimental condition (LPS) or the control condition (conventional lecture-based instruction). A pre-treatment baseline lesson on degree-radian conversion was delivered to both groups before the intervention to establish comparable starting points. It is acknowledged that assigning each university to a single condition introduces a potential confound between institution and treatment; this limitation is addressed explicitly in the discussion.

Population and Sampling

The target population comprised 1,249 undergraduate 200-level STEM students (Mathematics, Engineering, and Physics) enrolled in courses covering circular measures at four private universities in Oyo State during the 2024/2025 academic session. Table 1 presents the population distribution.

Table 1: Population Distribution of STEM Students Across Private Universities in Oyo State

Private University	Male	Female	Total
Ajayi Crowther University, Oyo	283	165	448
Lead City University, Ibadan	376	227	603
Atiba University, Oyo	65	34	99
KolaDaisi University, Ibadan	66	33	99
Total	790	459	1,249*

*Note. *Total reflects students enrolled in courses explicitly covering circular measures in the 2024/2025 session. Source: Academic/Records Offices of listed institutions.*

Purposive and multistage sampling was employed. Universities were selected against three criteria: (i) the institution offers undergraduate programmes in Mathematics, Engineering, or Physics; (ii) circular measures is explicitly included in the 200-level Mathematics curriculum; and (iii) the institution provided formal approval for classroom-based research. Ajayi Crowther University (control) and Lead City University (experimental) were selected. From each institution, one intact 200-level STEM class was selected, yielding 60 participants per group and N = 120 in total.

A priori power analysis was conducted using G*Power (Faul et al., 2007). Based on a medium-to-large expected effect size (Cohen's $f = 0.40$), $\alpha = 0.05$, and power = 0.80, the minimum required sample for a one-way ANCOVA was N = 52. The obtained sample of N = 120 substantially exceeded this threshold (estimated post hoc power ≈ 0.99). Baseline English language proficiency was assessed using the 20-item English Proficiency Placement Instrument (EPPI; KR-20 = 0.82), which classified participants into low (bottom 30%), average (middle 40%), and high (top 30%) proficiency sub-groups.

Instrumentation

The primary achievement instrument was the researcher-developed Circular Measures Achievement Test (CMAT), comprising 30 four-option multiple-choice items covering: (i) angle measurement in degrees and radians; (ii) conversion between degrees and radians; (iii) arc length and sector area calculations; (iv) small-angle approximations; and (v) applications in angular velocity and real-world contexts. Each correct response was awarded one mark (maximum score: 30). Content validity was established through review by three experts one in English Language Education, one in Mathematics Education, and one in Educational Measurement and Evaluation. Reliability was determined via a pilot study with 30 students from uninvolved institutions; the KR-20 coefficient of 0.87 confirms strong internal consistency.

Instructional Treatments

The LPS integrated explicit language support at every stage of mathematical instruction, incorporating: (i) academic vocabulary development for terms such as radian, sector, arc, angular velocity, and subtend, with definitions, pronunciation guides, and contextual examples; (ii) Frayer models; (iii) sentence frames for procedural reasoning (e.g., "Since θ is in radians, I apply $s = r\theta$ because…"); (iv) cause-and-effect discourse structures; and (v) collaborative task cards. Role-play activities contextualised mathematical language within real-world practice. This approach operationalises Vygotskian ZPD scaffolding, providing guided support that is progressively withdrawn as student competence increases. The control group received conventional teacher-centred instruction: concept definition, formula derivation, worked examples, and individual practice, with emphasis on note-taking and procedural replication.

Procedure

The eight-week intervention was aligned with one academic term. Week 1: pre-test (CMAT) and EPPI administration. Week 2: baseline lesson using conventional instruction for both groups. Weeks 3–7: LPS delivery to the experimental group; conventional instruction continued for the control group. Week 8: post-test using the same 30 CMAT items in reordered sequence to minimise memory effects. University Mathematics lecturers from participating institutions served as research assistants and received one week of structured training (five sessions) on their assigned instructional strategy. Ethical approval and written informed consent were obtained before data collection commenced.

Data Analysis

Data were analysed using one-way ANCOVA with pre-test scores as the covariate and treatment group as the independent variable, controlling statistically for pre-existing differences in mathematical ability. Prior to ANCOVA, three diagnostic tests were conducted: (i) Levene's test for homogeneity of error variances; (ii) the test of homogeneity of regression slopes; and (iii) the Shapiro–Wilk test for normality of residuals. For H_{02}, a two-way ANCOVA was conducted incorporating treatment group, EPPI proficiency level, and their interaction. All analyses were conducted in SPSS Version 27 at the 0.05 level of significance. Effect sizes are reported as partial eta squared (η^2p), interpreted using Cohen's (1988) conventions: small ≥ 0.01, medium ≥ 0.06, large ≥ 0.14.

Results

Diagnostic Tests

Table 2 presents the results of the ANCOVA assumption checks.

Table 2: Diagnostic Tests for ANCOVA Assumptions

Test	Statistic	p-value	Interpretation
Levene's Test of Homogeneity of Error Variances	F(1, 118) = 0.91	.342	Assumption met
Test of Homogeneity of Regression Slopes	F(1, 116) = 0.38	.539	Assumption met
Normality of Residuals (Shapiro-Wilk)	W = 0.989	.091	Assumption met

Note. All assumption tests were conducted prior to ANCOVA. Source: Researcher's Fieldwork, 2025.

All three assumptions were satisfied: error variances were homogeneous across groups ($p = .342$); the covariate–dependent variable relationship did not differ significantly by group ($p = .539$); and residuals were approximately normally distributed ($W = 0.989$, $p = .091$).

Hypothesis 1: Main Effect of Language Proficiency-Based Instruction

H_{01} posited no significant effect of the LPS on academic achievement after controlling for pre-test scores. Table 3 presents the ANCOVA results.

Table 3: ANCOVA Results for the Effect of Language Proficiency-Based Instruction on Post-Test Achievement

Source	SS	df	MS	F	p	η²p
Pre-test (Covariate)	1,247.56	1	1,247.56	458.32	< .001	.796
Treatment Group	917.06	1	917.06	336.84	< .001	.742
Error	319.06	117	2.73	—	—	—
Total (Corrected)	2,483.68	119	—	—	—	—

Note. η²p = partial eta squared (effect size). All df are corrected for the covariate. Source: Researcher's Fieldwork, 2025.

The ANCOVA revealed a statistically significant main effect of the LPS on post-test academic achievement, $F(1, 117) = 336.84$, $p < .001$, $\eta^2p = .742$. H_{01} was therefore rejected. The effect size indicates that approximately 74% of the variance in post-test scores was associated with treatment group membership after controlling for pre-existing ability a large effect by conventional standards (Cohen, 1988). The magnitude of this effect warrants critical commentary, addressed in the discussion.

Table 4 presents the estimated marginal means (adjusted for pre-test scores) by treatment group and proficiency sub-group.

Table 4: Estimated Marginal Means by Treatment Group and Proficiency Level (Adjusted for Pre-Test Scores)

Treatment Group	Low M (SE)	Average M (SE)	High M (SE)
Conventional Instruction	16.45 (0.42)	18.37 (0.21)	20.29 (0.42)
Language Proficiency-Based (LPS)	23.48 (0.41)	25.37 (0.21)	27.26 (0.41)

Note. Means and SEs are adjusted for pre-test scores. Proficiency levels based on EPPI scores: low = bottom 30%, average = middle 40%, high = top 30%. Source: Researcher's Fieldwork, 2025.

Across all three proficiency sub-groups, LPS students substantially outperformed the conventional instruction group. The overall adjusted mean for the LPS group ($M = 25.37/30$; 84.6%) was markedly higher than that of the conventional group ($M = 18.37/30$; 61.2%), representing a mean difference of 7.00 points.

Hypothesis 2: Moderation by Language Proficiency Level

A two-way ANCOVA incorporating treatment group, proficiency level (low/average/high), and their interaction was conducted to test H_{02}. The Treatment Group × Proficiency Level interaction was not statistically significant, $F(2, 113) = 1.83$, $p = .165$, $\eta^2p = .031$, indicating that the effect of the LPS did not differ significantly across the three proficiency sub-groups. H_{02} was therefore retained. The LPS was consistently beneficial regardless of students' baseline English proficiency, suggesting that its scaffolding mechanisms were effective across the range of linguistic ability in the sample.

Discussion of Findings

The results demonstrate that the language proficiency-based instructional strategy significantly improved post-test academic achievement in circular measures among undergraduate STEM students at private universities in Oyo State, Nigeria, relative to conventional lecture-based instruction. This finding is consistent with and extends a body of evidence establishing the role of language in mathematical learning in multilingual educational contexts.

Evidence from the wider literature supports the theoretical and empirical grounding of these findings. Abdullahi (2020) demonstrated that English language proficiency functions as a significant predictor of academic achievement across subject domains in Nigerian universities. Appalanaidu, Setambah and Ibrahim (2025) confirmed that the linguistic demands of STEM discourse including discipline-specific vocabulary, complex syntactic structures, and genre-specific conventions necessitate explicit language development if students are to access content effectively. Kamasak, Sahan and Rose (2021) similarly found that language proficiency specifically predicts Mathematics achievement among STEM undergraduates at English-medium institutions. The present findings are thus theoretically coherent with Vygotsky's (1962) position that language is the primary tool through which mathematical thought is organised and communicated.

The effect size obtained in this study ($\eta^2 p = .742$) is notably large and merits critical scrutiny. Several factors may have contributed to an inflated estimate. First, the quasi-experimental design confounds treatment with institutional membership: students at Ajayi Crowther University constituted the entire control group, and students at Lead City University constituted the entire experimental group. Unmeasured institutional differences including teaching staff quality, facilities, and student intake profiles cannot be entirely ruled out as contributing factors. Second, instructor effects are plausible, as lecturers delivering instruction were aware of their treatment assignment. Third, the novelty of the LPS may have produced a motivational boost among experimental group students. Future research employing multi-school randomised designs, blinded instructor delivery, and longer intervention periods will be needed to obtain a more precise estimate of the true treatment effect.

The finding that the treatment effect did not differ significantly across baseline language proficiency levels (H_{02} retained) is encouraging for practitioners. It suggests that the scaffolding mechanisms of the LPS vocabulary instruction, sentence frames, Frayer models, and collaborative discourse were effective for students at all levels of English proficiency, not only for those with high baseline competence. This implies broad applicability within linguistically heterogeneous classrooms. It is also worth acknowledging that the absence of contradictory evidence in the literature review does not confirm universal effectiveness: the empirical base remains limited, and the boundary conditions of these findings require investigation in public universities, other Nigerian states, and other mathematical topics.

Conclusion

This study provides evidence that a language proficiency-based instructional strategy significantly enhanced the academic achievement of private university STEM students in circular measures, relative to conventional instruction, in a quasi-experimental study conducted in Oyo State, Nigeria. Students in the LPS group achieved substantially higher adjusted mean post-test scores (84.6%) compared with the conventional instruction group (61.2%), and this effect was consistent across students with low, average, and high baseline English proficiency levels. These findings are theoretically grounded in Vygotsky's sociocultural theory, which identifies language as the primary cognitive tool through which mathematical meaning is constructed, and the ZPD as the space within which instructional scaffolding is most effective.

The study is qualified by several limitations. The quasi-experimental design introduces an institutional confound that cannot be fully eliminated through statistical control. The large observed effect size may be partially attributable to institutional differences, instructor effects, and the novelty of the intervention. The study was conducted over a single academic term at two private universities in one Nigerian state, limiting generalisability. Future research should employ multi-institution randomised designs, incorporate fidelity checks and instructor blinding, extend the intervention period, and examine long-term retention of conceptual gains. Notwithstanding these limitations, the present study makes a meaningful contribution to the empirical literature on language and STEM achievement in the Nigerian higher education context.

Recommendations

Based on the findings and their interpretation within the broader literature, the following recommendations are proposed. First, Mathematics lecturers in STEM programmes should systematically integrate language-focused activities including vocabulary scaffolding, sentence frames, Frayer models, and structured peer discourse into their instructional practice; the LPS lesson plan framework developed for this study provides a replicable model. Second, pre-service and in-service teacher education programmes should include explicit preparation in language-responsive pedagogy for STEM instruction. Third, private universities in Oyo State and Nigerian higher education institutions more broadly should revise their Mathematics curriculum frameworks to formally incorporate language-focused pedagogical approaches, particularly for abstract topics such as circular measures, limits, and differential equations. Fourth, replication studies are needed in public universities, in other Nigerian states, and with other mathematical topics; randomised controlled trials with multiple institutions per condition would address the institutional confound identified in this study; longitudinal designs should assess whether achievement gains are sustained beyond the immediate post-intervention period.

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