



Voice-Based Conversational User Interfaces for Enhancing Accessibility in Learning Environments: A Mixed-Methods Study in Enugu State, Nigeria

Chidi Agbo N.

Department of Curriculum and Instruction, Federal College of Education, Eha-Amufu, Enugu State, Nigeria

* Corresponding author

ABSTRACT

Accessible digital learning remains uneven in Nigerian public education, including in Enugu State, where inclusive-education policy exists but assistive tools, teacher preparation, and multimodal content are still limited. This mixed-methods study examined whether a bilingual (English and Igbo) voice-based conversational user interface (CUI) could improve accessibility, engagement, usability, and short-term learning outcomes relative to conventional graphical learning platforms. A pretest–posttest control-group design was implemented over six weeks with 248 senior secondary and first-year tertiary students from 10 public institutions in Enugu urban and peri-urban local government areas. Seventy-six participants had documented visual, motor, or specific learning difficulties. The experimental group ($n = 124$) used OluLearn, a speech-in/speech-out tutoring and content-access assistant aligned with Universal Design for Learning; the control group ($n = 124$) continued with existing teacher-led and GUI-based materials. Data were collected with an accessibility scale, the System Usability Scale, an engagement inventory, Technology Acceptance Model items, curriculum-aligned quizzes, task logs, and 24 semi-structured interviews. After the intervention, the CUI group reported higher perceived accessibility ($M = 3.89$ vs. 2.54), higher engagement ($M = 4.06$ vs. 3.14), higher quiz scores ($M = 73.18$ vs. 62.41), and higher usability ($SUS = 79.12$ vs. 57.86). Gains were larger among students with visual or motor impairments. Perceived usefulness and ease of use jointly explained 56% of the variance in intention to use. Qualitative themes highlighted hands-free access, Igbo voice support, and reduced dependence on print, alongside constraints of noise, connectivity, and speech-recognition accuracy for local accents. The findings support voice-first CUIs as a feasible accessibility layer for Enugu learning environments if they are bilingual, multimodal, and paired with teacher training and reliable power and network infrastructure.

Keywords: conversational user interface; voice user interface; accessibility; inclusive education; Universal Design for Learning; Technology Acceptance Model; Enugu; Nigeria

HOW TO CITE THIS ARTICLE

Agbo, C. N. (2026). Voice-based conversational user interfaces for enhancing accessibility in learning environments: A mixed-methods study in Enugu State, Nigeria. *Africa Journal of Engineering for Impact*, 1(1), 2–8.

1. Introduction

Digital learning tools are now common in Nigerian secondary and tertiary classrooms, yet many of those tools still assume vision, fine-motor control, fluent English literacy, and stable screen-based interaction. Students who are blind or have low vision, students with motor impairments, and students with specific learning difficulties therefore meet a second barrier after they have already entered school: the interface itself. Conversational user interfaces (CUIs), especially voice-based systems that accept speech and return spoken feedback, offer an alternative channel that can reduce dependence on keyboards, small targets, and dense visual layouts [1], [2].

Enugu State is a useful site for this problem. The state approved an inclusive-education policy in the mid-2010s and has continued to operate special education centres alongside mainstream placement [3]. Recent state investment in Smart Green Schools, digital classrooms, and teacher upskilling through platforms such as the Nigerian Learning Passport has expanded technology access. At the same time, empirical work in Enugu still reports weak implementation of inclusive practice, scarce teaching aids, limited teacher preparation for neurodevelopmental and sensory disabilities, and uneven assistive technology [4]–[6]. Nationally, the Discrimination Against Persons with Disabilities (Prohibition) Act (2018) and the National Policy on Inclusive Education require accessible public education, but practice lags policy [7], [8].

Voice-based CUIs are not a complete solution. Speech systems can exclude users with atypical speech, impose memory load, fail in noisy classrooms, and encode accent bias [9]. They can, however, supply multiple means of representation and action, which is the core of Universal Design for Learning [10], [11]. When a learner can ask a question aloud, hear a worked example, switch to Igbo, or fall back to text, the same lesson becomes usable by a wider group.

This study designed and evaluated OluLearn, a bilingual English–Igbo voice-based CUI for content access, guided practice, and task support in Enugu learning environments. The study asked whether six weeks of CUI use would improve perceived accessibility, engagement, usability, short-term achievement, and intention to adopt, and whether benefits would be stronger for students with visual or motor impairments.

2. Literature Review

2.1 Accessibility gaps in Enugu and Nigerian learning environments

Inclusive education in Nigeria is anchored in the Universal Basic Education Act, the National Policy on Education, the 2018 disability rights statute, and the revised National Policy on Inclusive Education [7], [8], [12]. Article 24 of the Convention on the Rights of Persons with Disabilities likewise requires inclusive, accessible education [13]. Implementation evidence from Enugu is less encouraging. Enwuru [4] found that state policy has not reliably produced enrolment supports, adequate teaching aids, or administrative capacity. Onyishi [5] reported that teachers in Enugu primary and secondary schools rarely used targeted inclusive practices for learners with neurodevelopmental disorders and felt unprepared. Okoroikpa's case study of a therapeutic inclusive secondary school in Enugu showed more positive staff attitudes where the environment was intentionally adapted, which implies that design of the setting, not policy text alone, drives experience [6].

At the tertiary level in the South-East, Nzewke et al. [14] documented that screen readers, speech-to-text tools, voice-recognition software, and text-to-speech systems are among the more available and effective digital assistive options, yet adaptive hardware and consistent institutional support remain uneven. These findings justify an intervention that uses speech as a first-class learning channel rather than as an afterthought bolted onto a visual learning-management system.

2.2 Conversational and voice interfaces in education

CUIs include chatbots, voice assistants, and mixed spoken–typed dialogue systems. Educational CUI research has moved from isolated command-and-control prototypes toward dialogue that can scaffold explanation, disclosure of needs, and collaborative revision [1], [15]. Metatla et al. [2] co-designed school voice interfaces with mixed-visual-ability pupils and showed that voice user interfaces can support shared revision, peer instruction, and classroom participation when they are not treated as private headphones-only tools. Iniesto et al. [15] demonstrated that a virtual assistant for disability disclosure was preferred to a static form by most students and that multimodal choice (voice and text) was itself an accessibility feature. Lister et al. [1] assembled design considerations for accessible CUIs across sensory, motor, cognitive, and mental-health needs and noted the scarcity of operational guidance.

Voice can also change the cognitive ecology of a task. Spoken guidance can keep eyes on a problem space rather than on a menu and can reduce the split-attention cost of screen-reader-plus-visual-layout workflows [16], [17]. For emergent users and bilingual communities, local-language speech recognition and generation are not optional extras; they determine whether the system is usable at all [18], [19].

2.3 Theoretical framework

Two complementary frameworks guided design and measurement. Universal Design for Learning specifies multiple means of engagement, representation, and action and expression [10]. A voice-first CUI operationalises UDL by offering auditory representation, spoken response, adjustable pace, and optional text fallback. The Technology Acceptance Model and its unified extension treat perceived usefulness and perceived ease of use as proximal predictors of intention to use [20], [21]. In a resource-constrained school system, intention is not only a psychological variable; it is a proxy for whether teachers and students will keep a prototype after the research team leaves. The study therefore treated accessibility outcomes and acceptance outcomes as jointly necessary.

2.4 Research questions and hypotheses

Four questions structured the inquiry:

- RQ1. Does a bilingual voice-based CUI improve perceived accessibility relative to existing GUI and print-mediated practice in Enugu learning environments?
- RQ2. Does CUI use improve engagement, task completion, and short-term learning outcomes?
- RQ3. Do perceived usefulness and ease of use predict intention to continue using the CUI?
- RQ4. Are accessibility and outcome gains larger for students with visual or motor impairments, and does Igbo voice support improve usability for Igbo-dominant learners?

The corresponding hypotheses were as follows:

- H1. Students in the CUI condition will report significantly higher posttest perceived accessibility than students in the control condition.
- H2. Students in the CUI condition will show significantly higher engagement, task-completion rates, and posttest quiz scores than students in the control condition.

H3. Perceived usefulness and perceived ease of use will significantly predict intention to use the CUI.

H4. The CUI advantage on accessibility and quiz scores will be larger among students with visual or motor impairments than among peers without those impairments.

H5. Among Igbo-dominant learners in the experimental group, bilingual voice interaction will be associated with higher usability and satisfaction than English-only interaction.

3. Methodology

3.1 Design and setting

A concurrent mixed-methods design combined a quasi-experimental pretest–posttest control-group study with embedded interviews [22]. Intact class groups were assigned to conditions because random assignment of individual students would have disrupted school timetables. The intervention lasted six instructional weeks in the second term of the 2025–2026 academic year.

Participants were 248 students (116 female, 132 male) aged 15–22 years ($M = 17.6$, $SD = 1.8$) drawn from six public senior secondary schools and four public tertiary institutions in Enugu North, Enugu East, Enugu South, Nsukka, and Nkanu West. Schools included both conventional public schools and sites participating in state digital-school upgrades. Inclusion criteria were enrolment in English Language or Basic/General Science for the study modules, ability to provide assent or consent, and access to a shared device or laboratory session at least twice weekly. Seventy-six students (30.6%) had a documented accessibility need: visual impairment ($n = 31$), motor impairment affecting handwriting or device use ($n = 22$), or a specific learning difficulty formally or provisionally identified by the school ($n = 23$).

Twenty-four informants (14 students, 10 teachers or learning-support staff) completed interviews. Teachers had between 4 and 27 years of experience. Institutional permission was obtained from school principals and heads of department. Parents or guardians consented for minors; students aged 18 and above consented for themselves.

3.2 The OluLearn voice-based CUI

OluLearn was a prototype speech-in/speech-out assistant deployed on Android tablets and laboratory PCs with headset microphones. Core functions were spoken retrieval of lesson summaries aligned to the sampled English and science topics; Socratic follow-up questions; worked-example narration; short oral quizzes with immediate feedback; task prompts for homework planning; and a help intent that restated instructions more slowly. Users could switch language between English and Igbo, reduce speech rate, repeat the last turn, or open a text transcript. The dialogue manager used intent classification over a constrained educational ontology rather than an unbounded open chatbot, which reduced hallucination risk in assessed content. Design choices followed accessible-CUI recommendations: multimodal fallback, explicit turn-taking cues, short turns, and tolerance for repair [1], [9], [15].

Control classrooms used the same curriculum topics through existing teacher explanation, printed notes, and whatever graphical resources the school already provided (projector slides, learning-management pages, or shared computers). No school was asked to withdraw existing accommodations.

3.3 Instruments and procedure

Perceived accessibility was measured with a 12-item Likert scale (1 = strongly disagree, 5 = strongly agree) covering ease of obtaining information, independence, sensory access, and error recovery. Cronbach's alpha was .89 at pretest and .91 at posttest. Usability was measured with the 10-item System Usability Scale, scored 0–100 [23]. Engagement was measured with a 10-item scale covering behavioural, emotional, and cognitive engagement [24]. Technology Acceptance Model constructs used four perceived-usefulness items, four ease-of-use items, and three intention items [20], [21]. Learning outcomes were 20-item curriculum-aligned quizzes written with participating teachers, parallel in difficulty at pretest and posttest, scored 0–100. Two teachers independently rated a 20% subsample of constructed-response items (Cohen's $\kappa = .81$). Task completion was the percentage of assigned practice tasks finished within the weekly window.

Week 0 comprised ethics briefing, baseline questionnaires, and the pretest quiz. Experimental classes received a 40-minute orientation on headset use, wake phrasing, language switching, and repair strategies. Weeks 1–6 delivered two supervised sessions per week (35–40 minutes) plus optional after-school access in three schools with functioning laboratories. Teachers remained in the room. Week 6 repeated the quantitative battery and the posttest quiz. Interviews were conducted in Weeks 5–7 in English or Igbo according to informant preference.

Analyses used IBM SPSS Statistics 29. Missing item values below 5% were imputed with scale means. H1 and H2 were tested with ANCOVA (posttest controlling for pretest). H4 used two-way ANCOVA with condition and impairment group as factors. H3 used hierarchical multiple regression. H5 compared bilingual-session users with English-only session users inside the experimental group. Alpha was .05. Interview transcripts were analysed with reflexive thematic analysis [25].

4. Results

4.1 Preliminary analyses

The groups did not differ at pretest on accessibility, engagement, or quiz scores (all p s > .40). Sex, school type, and impairment status were similarly distributed (Table 1). All multi-item scales exceeded the conventional .70 reliability threshold (Table 2).

Table 1. Demographic characteristics of participants.

Characteristic	CUI (n = 124)	Control (n = 124)	Full sample	p
Female, n (%)	57 (46.0)	59 (47.6)	116 (46.8)	.80
Male, n (%)	67 (54.0)	65 (52.4)	132 (53.2)	
Age in years, M (SD)	17.5 (1.7)	17.7 (1.9)	17.6 (1.8)	.38
Secondary school, n (%)	79 (63.7)	81 (65.3)	160 (64.5)	.79
Tertiary, n (%)	45 (36.3)	43 (34.7)	88 (35.5)	
Visual impairment, n	16	15	31	.91
Motor impairment, n	11	11	22	1.00
Learning difficulty, n	12	11	23	.83
No documented impairment, n	85	87	172	.78
Igbo-dominant home language, n (%)	81 (65.3)	78 (62.9)	159 (64.1)	.69

Note. p values are from chi-square tests for categorical variables and an independent-samples t test for age.

Table 2. Scale reliability and descriptive statistics at posttest.

Scale	Items	α	Range	Sample M (SD)
Perceived accessibility	12	.91	1–5	3.22 (0.89)
Engagement	10	.88	1–5	3.60 (0.74)
Perceived usefulness	4	.90	1–5	3.71 (0.81)
Perceived ease of use	4	.86	1–5	3.58 (0.77)
Intention to use	3	.84	1–5	3.64 (0.88)
System Usability Scale	10	.87	0–100	68.49 (16.21)

Note. Reliability coefficients are Cronbach's alpha.

4.2 Perceived accessibility, engagement, and learning

ANCOVA with pretest accessibility as covariate showed a large condition effect on posttest accessibility, $F(1, 245) = 214.63$, $p < .001$, partial $\eta^2 = .47$. Adjusted posttest means were 3.88 for the CUI group and 2.55 for the control group. H1 was supported. The CUI group also outperformed the control group on posttest engagement, task completion, and quiz scores after pretest adjustment (Table 3). Effect sizes were large for engagement and task completion and medium-to-large for quiz scores. H2 was supported.

Table 3. Pretest and posttest means by condition.

Outcome	CUI pre	CUI post	Ctrl pre	Ctrl post	d
Accessibility	2.41 (0.61)	3.89 (0.53)	2.38 (0.58)	2.54 (0.60)	2.38
Engagement	3.08 (0.66)	4.06 (0.51)	3.11 (0.64)	3.14 (0.62)	1.62
Quiz score	54.22 (12.41)	73.18 (10.86)	53.87 (11.95)	62.41 (12.20)	0.93
Task completion %	61.4 (14.8)	86.7 (9.6)	62.1 (15.2)	68.3 (13.4)	1.58
SUS (post only)	—	79.12 (9.84)	—	57.86 (12.17)	1.92

Note. Ctrl = control. d = Cohen's d for the unadjusted posttest contrast. All posttest contrasts $p < .001$. Quiz scores are percentages.

4.3 Interaction with impairment status

A two-way ANCOVA on posttest accessibility yielded a condition $\times$ impairment interaction, $F(1, 243) = 9.47$, $p = .002$, partial $\eta^2 = .04$. Simple-effects analysis showed that the CUI advantage was larger for students with visual or motor impairments (adjusted mean difference = 1.61) than for students without those impairments (adjusted mean difference = 1.18). The same pattern appeared for quiz scores, $F(1, 243) = 5.82$, $p = .017$, partial $\eta^2 = .02$. Students with specific learning difficulties in the CUI group also improved, but their increment did not exceed that of unimpaired peers at conventional significance. H4 was supported for visual and motor impairment (Table 4).

Table 4. Posttest accessibility and quiz scores by condition and impairment group.

Group	n	Accessibility M (SD)	Quiz M (SD)
CUI, visual/motor	27	4.12 (0.41)	74.96 (9.72)
Control, visual/motor	26	2.31 (0.57)	58.04 (11.88)
CUI, other/none	97	3.83 (0.54)	72.68 (11.16)

Group	n	Accessibility M (SD)	Quiz M (SD)
Control, other/none	98	2.60 (0.59)	63.57 (12.14)

Note. Visual/motor combines documented visual and motor impairments. Other/none includes specific learning difficulties and students with no documented impairment.

4.4 Predictors of intention to use

Among experimental-group students, perceived usefulness and ease of use correlated with intention (Table 5). Hierarchical regression entered age and impairment status in Step 1 ($R^2 = .04$, $p = .08$) and the two TAM predictors in Step 2. Step 2 produced $\Delta R^2 = .52$, $F(2, 119) = 71.38$, $p < .001$. In the final model, usefulness ($\beta = .48$, $p < .001$) and ease of use ($\beta = .31$, $p < .001$) were both significant. H3 was supported. The final model explained 56% of the variance in intention (Table 6).

Table 5. Correlations among posttest variables in the CUI group ($n = 124$).

Variable	1	2	3	4	5
1. Accessibility	—				
2. Usefulness	.58**	—			
3. Ease of use	.51**	.57**	—		
4. Engagement	.49**	.54**	.46**	—	
5. Intention	.52**	.67**	.58**	.50**	—
6. SUS	.47**	.55**	.62**	.41**	.53**

Note. ** $p < .01$. SUS = System Usability Scale.

Table 6. Hierarchical regression predicting intention to use the CUI.

Predictor	B	SE B	β	p
Step 1				
Age	−0.04	0.04	−.08	.31
Visual/motor impairment	0.28	0.16	.14	.08
Step 2				
Age	−0.02	0.03	−.04	.48
Visual/motor impairment	0.11	0.11	.05	.33
Perceived usefulness	0.49	0.08	.48	<.001
Perceived ease of use	0.34	0.08	.31	<.001

Note. Step 1 $R^2 = .04$; Step 2 $R^2 = .56$, $\Delta R^2 = .52$, $p < .001$.

4.5 Bilingual voice support

Within the CUI group, 81 students were Igbo-dominant. Of these, 49 used bilingual sessions for at least half of logged turns; 32 stayed in English only. Bilingual users reported higher SUS scores ($M = 82.44$, $SD = 8.21$) than English-only Igbo-dominant peers ($M = 74.09$, $SD = 10.05$), $t(79) = 4.07$, $p < .001$, $d = 0.92$, and higher satisfaction ($M = 4.28$ vs. 3.71 on a 5-point item). H5 was supported.

4.6 Qualitative findings

Six themes were developed from the interviews (Table 7). Students with low vision described the CUI as reducing waiting time for a reader and making revision possible after school. Several motor-impaired students emphasised hands-free control. Teachers valued the worked-example narration but worried about classroom noise, shared headsets, and whether spoken answers could be trusted for high-stakes content. Igbo voice output was described as closer to how concepts are explained at home, but recognition errors rose with rapid code-switching and with strong local accent variation. Infrastructure—power cuts, weak laboratory Wi-Fi, and insufficient devices—was the most frequently named threat to sustainability.

Table 7. Summary of qualitative themes.

Theme	Sources (n)	Illustrative point
Independence from print and helpers	18	Voice access reduced reliance on a sighted reader or copyist.
Bilingual comfort	15	Igbo turns lowered hesitation and supported concept talk.
Hands-free and low-vision fit	12	Motor and visual groups described fewer interface fights.
Noise and recognition errors	16	Open classrooms and accent mismatch caused failed turns.
Trust and pedagogical role	11	Teachers wanted teacher-approved content, not open chat.
Infrastructure and staffing	20	Power, devices, and training were conditions of continued use.

Note. Sources are unique informants who contributed to the theme. N interviews = 24.

5. Discussion

This study provides Enugu-based evidence that a constrained, bilingual voice-based CUI can raise perceived accessibility, engagement, task completion, and short-term quiz performance relative to business-as-usual digital and print practice. The accessibility effect was large and was amplified for students with visual or motor impairments, which is consistent with the claim that speech can remove a channel barrier that graphical interfaces leave intact [2], [19]. The finding does not imply that voice is universally superior. Students with learning difficulties improved with the CUI but did not show a distinctive extra increment, and interviews flagged memory load when spoken turns were long—an issue anticipated in cognitive-accessibility guidance for voice systems [9].

The Technology Acceptance Model results replicate a familiar pattern in a less familiar setting. Usefulness mattered more than ease of use, as Davis [20] originally observed, but ease of use remained a significant predictor. In Enugu classrooms that share devices and absorb power cuts, ease includes whether a headset works, whether the wake phrase is recognised through an Igbo-accented English request, and whether a failed turn can be repaired without a technician. SUS scores in the high 70s for the CUI sit in the good band of published benchmarks [23], [26] and contrast with the control group's evaluation of existing graphical tools.

Bilingual interaction was not a cosmetic localisation. For Igbo-dominant learners it was associated with a nearly one-standard-deviation usability advantage. That result aligns with work on emergent users and multilingual voice systems [18] and with Nigerian evidence that natural-language fit enables virtual-assistant use among students [27]. It also qualifies Universal Design for Learning for this context: multiple means of representation must include language, not only modality.

The Enugu policy backdrop makes the practical implication sharper. State and national instruments already require accessible public education [4], [8], [12]. Smart Green Schools and related digital investments create device and connectivity conditions that earlier inclusive-education studies in the state did not have. A voice CUI is therefore not an exotic add-on; it is a way to spend those investments on learners who still cannot use a screen-first lesson. The qualitative data, however, warn against a device-only reading of the results. Teachers asked for approved content, quieter rooms or headsets, and training. Without those, recognition errors and mistrust will erase the measured gains.

5.1 Implications for practice and policy

First, state education authorities and school ICT units should treat speech input and output as a default accessibility layer on devices already being deployed in Smart Green Schools and tertiary laboratories, not as a specialist tool stored in a special-education office. Second, content should be teacher-curated and curriculum-bounded; open generative chat is a poor fit for assessed school topics. Third, Igbo and other community languages should be first-class voices, with accent data collected locally rather than imported. Fourth, teacher professional development—already a documented gap in Enugu inclusive practice [5]—should include CUI facilitation: how to stage a voice activity, how to handle failed recognition, and how to keep multimodal fallback available. Fifth, procurement specifications should include offline or low-bandwidth modes, because connectivity failures were a dominant implementation constraint.

5.2 Limitations

Intact-class assignment prevents strong causal claims about individual students and leaves room for teacher and school effects. The six-week window captures near-term change, not retention or transfer. Quiz items were teacher-built and local; they should not be read as standardised achievement tests. Speech recognition was evaluated only through logs and interviews, not through a separate word-error-rate study by accent group. Students with hearing impairment or complex communication needs were not the focus of the prototype and should not be assumed to benefit. Finally, the sample over-represents institutions that already had some laboratory capacity; rural schools with no reliable power may not reproduce these effect sizes.

6. Conclusion

A bilingual voice-based CUI improved accessibility, engagement, usability, and short-term learning outcomes in Enugu secondary and tertiary settings, with larger accessibility and achievement gains for students with visual or motor impairments. Usefulness and ease of use explained most of the variance in intention to continue. The results support CUIs as a practical instrument of Universal Design for Learning in a state that has policy language and growing digital infrastructure but still thin assistive practice. Scaling will depend less on a more fluent model and more on language, noise, power, teacher trust, and the decision to treat voice as part of ordinary classroom design.

Declarations

Funding. This research received no specific external grant.

Conflict of interest. The author declares no competing interests.

Data availability. Anonymised survey scores and task logs are available from the corresponding author on reasonable request.

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