

INTEGRATION OF ETHNO-BIOLOGY AND INDIGENOUS KNOWLEDGE SYSTEMS (IKS) IN SECONDARY SCHOOL BIOLOGY: EFFECTS ON STUDENT ENGAGEMENT, CONCEPTUAL UNDERSTANDING, AND RETENTION IN SOUTH-EAST NIGERIA

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Abstract

Persistent reports from the West African Examinations Council (WAEC) and the National Examinations Council (NECO) reveal that secondary school students in Nigeria struggle to grasp abstract concepts in Biology, particularly in areas such as genetics, ecology, and cellular respiration. At the same time, students in South-East Nigeria exhibit a profound, practical understanding of local flora and fauna (for instance, the medicinal applications of *Vernonia amygdalina* (bitter leaf), *Xylopiya aethiopica* (uda), and *Ocimum gratissimum* (scent leaf)), which they have acquired through Indigenous Knowledge Systems (IKS). Nevertheless, this ethno-biological knowledge is largely disconnected from formal educational settings. This study aimed to explore the degree to which the incorporation of Igbo ethno-biological knowledge into the teaching of challenging Biology topics enhances students' conceptual understanding, engagement, and long-term retention. A quasi-experimental pretest-posttest non-equivalent control group design was utilized. The participants consisted of 186 senior secondary school year two (SS2) students from four co-educational public schools located in Enugu and Anambra States (two experimental groups and two control groups). The experimental groups underwent a 6-week IKS-integrated Biology instruction, which included culturally contextualized lessons, indigenous classification tasks, ethno-medicinal plant analysis, and local ecological observations, while the control groups received traditional lecture-based instruction. The instruments used for assessment included the Biology Conceptual Understanding Test (BCUT, comprising 35 multiple-choice and 15 short-answer items, $r=0.87$), the Engagement Inventory (EI, a 5-point Likert scale, $\alpha=0.91$), and the Delayed Retention Test (identical to the BCUT, administered 6 weeks after the intervention). Qualitative data were gathered from 12 focus group discussions to complement the quantitative findings. The results of the ANCOVA indicated that students in the IKS-integrated group significantly outperformed those in the control group in terms of conceptual understanding (mean experimental=72.4%, SD=9.6; control=48.3%, SD=11.2; $F(1,183) =146.3$, $p<0.001$, $\eta^2=0.44$). Qualitative findings indicated that students perceived the integration of Indigenous Knowledge Systems (IKS) as "meaningful," "easier to recall," and "linking school to home." The incorporation of ethno-biology notably enhances the understanding of abstract concepts in Biology, boosts student engagement, and aids in the retention of knowledge over the long term. The study advocates for the establishment of a formal ethno-biology curriculum for senior secondary Biology, the professional development of teachers in IKS integration, and the acknowledgment of Indigenous knowledge as a valid pedagogical framework in policy.

1. Introduction

Science education worldwide continues to grapple with the enduring issue of rendering abstract concepts comprehensible, significant, and memorable for students (Hewson & Ogunniyi, 2011). This issue is particularly pronounced in post-colonial African secondary education systems, where the

curriculum is largely influenced by Western perspectives, language, and examples, while students' lived experiences are deeply rooted in rich, practical Indigenous Knowledge Systems (IKS) (Msimanga & Lelliot, 2014). In Nigeria, the senior secondary Biology curriculum encompasses subjects such as cell biology, genetics, ecology, nutrition, and reproduction (NERDC, 2018). External examination bodies—the West African Examinations Council (WAEC) and the National Examinations Council (NECO)—consistently indicate that Nigerian students struggle with questions that necessitate the application of abstract biological principles to unfamiliar scenarios (WAEC, 2019, 2021, 2022; NECO, 2020). In particular, subjects like genetics (e.g., Mendelian ratios, inheritance patterns), cellular respiration (e.g., glycolysis, ATP synthesis), and ecological concepts (e.g., food webs, energy flow, succession) are recognized as “notoriously difficult” (WAEC Chief Examiner’s Report, 2022, p. 14).

In tandem with this academic underachievement, students in South-East Nigeria are immersed in environments rich with ethno-biological knowledge. They witness their grandparents utilizing *Vernonia amygdalina* (bitter leaf) for malaria treatment; they observe the use of *Xylopia aethiopica* (uda) in postpartum care and *Ocimum gratissimum* (scent leaf) as an antiseptic; they engage in local taxonomy where plants are categorized by their uses (medicinal, spiritual, and nutritional) rather than by Linnaean classifications (Ani & Nwosu, 2019). They comprehend seasonal variations in local biodiversity and the behaviors of familiar animal species (e.g., the nesting habits of *Ploceus cucullatus* (village weaver) indicating impending rainfall). This knowledge, amassed over generations through direct observation and cultural transmission.

The view of Biology as “abstract” may appear contradictory, considering that it involves the study of living organisms, which are encountered by students on a daily basis. Nevertheless, this abstraction does not stem from the subject itself but rather from the gap between students' real-life experiences and the decontextualized, terminologically complex, Western-centric representations found in textbooks (Jegede & Aikenhead, 1999). For instance, the idea of “allele segregation” in genetics is often illustrated through hypothetical pea plants, a species that many Nigerian students may not relate to in agricultural or culinary contexts. In contrast, the same principle of trait inheritance can be clearly observed in the coat patterns of local goat breeds (such as the West African Dwarf) or the color variations in local chicken breeds (like Frizzle feather or Normal feather). Likewise, the notion of “ecological succession” is frequently taught using textbook illustrations depicting the transition from barren rock to forest, while students could witness succession occurring on abandoned farmlands (fallow plots) within their own communities, observing the re-emergence of specific pioneer and climax species (for example, *Chromolaena odorata* followed by *Musa paradisiaca*).

This disconnect is not solely a pedagogical issue but also a psychological and cultural one. When students view science as foreign, as a form of “Western knowledge” that disregards or overlooks their indigenous understandings, they encounter cognitive dissonance and disengagement (Aikenhead, 2006). This phenomenon, referred to as “collateral learning” by Jegede (1995), illustrates how students separate school science from everyday science, hindering the integration necessary for profound comprehension. Consequently, this leads to rote memorization for tests, quick forgetting, and a lasting perception of science as disconnected from their lives.

Indigenous Knowledge Systems (IKS) encompass the accumulated knowledge, practices, and beliefs that have developed over generations, deeply rooted in cultural interactions with the environment (UNESCO, 2018). Within the realm of Biology, IKS comprises ethno-botany (the uses and classification of plants), ethno-zoology (the study of animal behavior and their uses), ethno-ecology (including seasonal calendars and land management practices), ethno-medicine (healing methodologies), and ethno-taxonomy (folk classification systems). Contrary to being labeled as “primitive” or “unscientific,” IKS embodies a rational and empirical framework that is tailored to local contexts (Ogawa, 1995). For example, the classification of plants by Igbo traditional healers based on their effects on bodily systems (such as “blood purifiers” and “digestive tonics”) demonstrates a functional comprehension of phytochemistry, despite the differing terminology from Western biomedical language (Nwosu & Ani, 2021).

On a global scale, the incorporation of IKS into science education has been increasingly recognized. In South Africa, the Curriculum Assessment Policy Statements (CAPS) explicitly

incorporate indigenous knowledge as a component across various subjects (Department of Basic Education, 2011). In New Zealand, Māori knowledge (mātauranga Māori) is woven into the science curriculum. Similarly, in Canada, the ecological perspectives of First Nations are acknowledged as legitimate scientific frameworks (Aikenhead & Ogawa, 2007). However, in Nigeria, despite the National Policy on Education's emphasis on "preserving and promoting culture" (FRN, 2013), there remains a lack of systematic integration of IKS into the basic or senior secondary science curricula. Consequently, Biology educators predominantly depend on Western textbooks, laboratory manuals, and examples, largely overlooking the ethno-biological wealth that is present in their surroundings.

The Igbo ethnic group from South-East Nigeria has a notably well-documented ethno-biological heritage (Ani & Nwosu, 2019; Nwosu, 2015). The primary components include:

1. Ethno-taxonomy: Plants are categorized based on their medicinal properties (ogwu), nutritional benefits (nri), spiritual importance (ofo/alusi), or practical uses (nkpuchi/izu). This system differs from the Linnaean classification (family, genus, and species) yet remains equally rational.

2. Ethno-medicine: More than 300 plant species are utilized in traditional Igbo medicine (Okonkwo & Okonkwo, 2020). For instance: *Vernonia amygdalina* (bitter leaf, olugbu) is used for malaria and fever; *Gongronema latifolium* (utazi) aids in digestion; *Xylopia aethiopica* (uda) is employed for coughs, postpartum care, and as a spice; *Ocimum gratissimum* (scent leaf, nchanwu) serves antiseptic and anti-inflammatory purposes.

3. Animal ethno-ecology: Igbo farmers monitor livestock behavior to forecast weather patterns; for example, the construction of higher mounds by termites indicates impending heavy rains, while specific bird calls (eze-ngwere) signal seasonal transitions.

4. Indigenous agricultural practices: Techniques such as crop rotation, intercropping (e.g., yam, maize, and melon), fallow systems, and soil fertility management through the use of *Chromolaena odorata* as green manure demonstrate an ecological comprehension of nutrient cycling, competition, and succession.

5. Spiritual ecology: Sacred groves (osisi na ala mmuo) function as informal conservation areas that protect biodiversity, showcasing an understanding of habitat preservation.

In spite of this extensive knowledge, formal Biology education in Igbo-speaking regions still relies on Western examples: genetics is taught using Mendel's peas instead of local bean varieties (*Vigna unguiculata*); ecology is presented through hypothetical food webs rather than actual local farm ecosystems; and plant taxonomy is instructed with foreign species like *Hibiscus rosa-sinensis* (Chinese hibiscus) instead of native *Hibiscus sabdariffa* (zobo leaf).

1.1. This research is based on three interrelated theoretical frameworks:

1. Socio-Cultural Constructivism (Vygotsky, 1978): Learning is facilitated through social interactions and the use of cultural tools. The Biology classroom serves as a cultural environment; when this environment disregards the home cultures of students, the "zone of proximal development" becomes unreachable. The incorporation of Indigenous Knowledge Systems (IKS) offers familiar cultural supports (such as local plant names and communal medicinal knowledge) that can be linked to abstract scientific ideas.

2. Collateral Learning Theory (Jegade, 1995): In non-Western settings, students experience what is termed "collateral learning"; they maintain parallel, often contradictory, knowledge systems (everyday IKS and academic science) without integrating them. Effective science education necessitates "harmonious collateral learning," where these two knowledge systems are explicitly connected rather than left in conflict. This research implements that connection by utilizing IKS as the foundation for scientific abstraction.

3. Culturally Relevant Pedagogy (Ladson-Billings, 1995): The likelihood of academic success increases when teaching is culturally relevant (validating students' identities), culturally responsive (employing cultural references as supports), and culturally sustaining (preserving cultural competence). The integration of ethno-biology encompasses all three aspects: it recognizes Igbo knowledge as valid, employs familiar instances to elucidate abstract concepts, and ensures the transmission of Indigenous knowledge across generations.

Despite the policy discourse surrounding cultural relevance, the Biology curriculum in Nigerian secondary schools remains predominantly Western in its content, examples, and teaching methods. Students in South-East Nigeria possess extensive ethno-biological knowledge regarding local plants and animals, yet this knowledge is neither recognized nor utilized in formal education. At the same time, reports from WAEC and NECO consistently highlight "abstract" Biology topics such as genetics, ecology, and cellular respiration as areas where students struggle significantly. The disconnection between everyday ethno-biological expertise and the decontextualized school science curriculum likely contributes to low levels of engagement, inadequate understanding, and swift forgetting. There exists a scarcity of empirical research in Nigeria that investigates whether the intentional and structured incorporation of Igbo ethno-biological knowledge enhances students' conceptual understanding and retention of challenging Biology subjects. This study aims to fill that gap.

1.2. Research Questions

The research was directed by the following inquiries:

1. How does IKS-integrated Biology instruction influence students' comprehension of challenging subjects (genetics, ecology, and cellular respiration) in comparison to traditional instruction?
2. How does IKS-integrated Biology instruction affect students' engagement (behavioral, cognitive, and emotional) relative to conventional teaching methods?
3. How does IKS-integrated Biology instruction impact students' long-term retention (measured by a 6-week delayed post-test) of biological concepts when compared to traditional instruction?
4. What are students' views on the IKS-integrated approach in terms of meaningfulness, difficulty, cultural relevance, and its connection to their home knowledge?

Hypotheses

H₀₁: There is no significant difference in average conceptual understanding scores between students who received IKS-integrated Biology instruction and those who underwent conventional instruction, after adjusting for pretest scores.

H₀₂: There is no significant difference in average engagement scores between the groups receiving IKS-integrated instruction and those receiving conventional instruction.

H₀₃: There is no significant difference in average retention scores (as measured by a delayed post-test) between the IKS-integrated instruction group and the conventional instruction group.

2. Materials and Methods

2.1. Research Design

A quasi-experimental pretest-posttest non-equivalent control group design was utilized. This design is suitable when it is impractical to randomly assign intact classes to different conditions, as is often the case in public secondary schools, yet a comparison group is essential for inferring treatment effects (Creswell & Creswell, 2018). The design is illustrated as follows:

Group	Pretest	Intervention	Immediate Posttest	Delayed Posttest (6 weeks)
Experimental	O1	IKS-integrated Biology	O2	O3
Control	O4	Conventional Biology	O5	O6

2.2. Study Area

The study was conducted in two states of South-East Nigeria: Enugu State (specifically Nsukka Education Zone) and Anambra State (Awka Education Zone). These zones were selected because they: (a) have predominantly Igbo-speaking populations with strong continuity of traditional ethno-biological practices; (b) contain rural/peri-urban schools with students who have direct exposure to indigenous knowledge (farming, traditional medicine, local biodiversity); and (c) were accessible for the six-week intervention period without major security disruptions typical of other South-East zones.

2.3. Population and Sampling

Population: All 5,412 senior secondary school year two (SS2) students offering Biology in public co-educational schools in Enugu and Anambra States (as of 2023 enrollment data).

2.3.1. Sampling Procedure: A multi-stage purposive and random sampling procedure was used.

- Stage 1 (Purposive): Two Education Zones (Nsukka in Enugu, Awka in Anambra) were purposively selected based on accessibility and safety.

- Stage 2 (Purposive): From each zone, two co-educational public secondary schools were purposively selected based on: (a) availability of laboratory facilities (minimal standard), (b) willingness of principal and Biology teachers to participate, (c) similar class sizes (SS2 enrollment between 40–60 students), and (d) not previously exposed to IKS-integrated instruction. This yielded four schools: two experimental (one in Enugu, one in Anambra) and two control (one in Enugu, one in Anambra).

- Stage 3 (Whole-class sampling): All SS2 Biology students in the selected schools were included (intact classes). Total sample: 186 students (experimental $n=94$; control $n=92$). The gender distribution was 98 males (52.7%), 88 females (47.3%). Age range 15–18 years (mean=16.3 years).

Equivalence of groups: Pretest scores on BCUT were compared: experimental mean=41.2 (SD=12.4), control mean=42.1 (SD=11.8); independent t-test $t(184)=0.51$, $p=0.61$, confirming no significant pre-existing difference.

2.4. Instruments

Four instruments were developed and validated for this study.

2.4.1. Instrument 1: Biology Conceptual Understanding Test (BCUT)

The BCUT was created to assess students' conceptual grasp of three challenging subjects: Genetics (12 items), Ecology (12 items), and Cellular Respiration (11 items), culminating in a total of 35 multiple-choice questions (each with four options) alongside 15 short-answer questions that necessitate explanation or application (for instance, "Elucidate how the principle of segregation observed in Mendel's peas is reflected in the coat color inheritance of West African Dwarf goats"). The maximum achievable score on the BCUT was 85 (35 MCQs at 1 mark each = 35; 15 short-answer questions at 1–3 marks based on depth = 50).

Development process: The items were formulated based on WAEC/NECO syllabi, previous examination questions (2015–2022), and the NERDC Biology curriculum. Content validity was verified by three experts: two specializing in Biology education (University of Nigeria, Nsukka) and one curriculum expert (NERDC). The content validity index (CVI) was determined to be 0.91. The BCUT underwent a pilot test with 45 SS2 students from a non-participating school (Ebonyi State). The reliability, assessed using Kuder-Richardson (KR-20), was found to be 0.87. Scoring rubrics for short-answer responses were established, and inter-rater reliability between two independent evaluators was calculated at $r=0.89$.

2.4.2. Instrument 2: Engagement Inventory (EI)

The EI evaluated three aspects of engagement (behavioral, cognitive, emotional) through 15 items rated on a 5-point Likert scale (1=Strongly Disagree to 5=Strongly Agree). Example items include: "I look forward to Biology class" (emotional), "I strive to relate what we learn to my prior knowledge from home" (cognitive), and "I actively engage in class discussions" (behavioral). The Cronbach's alpha for the entire scale was 0.91 (subscale scores: behavioral 0.84, cognitive 0.87, and emotional 0.88).

2.4.3. Instrument 3: Delayed Retention Test (DRT)

The DRT was structurally and content-wise identical to the BCUT, comprising the same 35 multiple-choice questions (MCQs) and 15 short answer questions, albeit re-ordered and re-worded to minimize the recall of specific answers while still assessing the same constructs. The objective was to evaluate retention six weeks following the immediate post-test, with no instructional guidance provided during the intervening period.

2.4.4. Instrument 4: Focus Group Discussion Guide

A semi-structured focus group discussion (FGD) guide was utilized to investigate students' perceptions regarding the IKS-integrated approach. Sample inquiries included: "Can you elaborate on how the use of local plants such as bitter leaf or uda facilitated or hindered your understanding of Biology?"; "Do you perceive the Biology topics as being easier or more challenging when linked to familiar concepts from home?"; "Should Biology consistently be taught in this manner? Please explain your reasoning." A total of twelve focus groups, each consisting of 6-8 students, were conducted within the experimental schools.

2.5. Development of IKS-Integrated Biology Instructional Module

A six-week instructional module was created, addressing the three focal topics (genetics, ecology, cellular respiration) with a clear integration of Igbo ethno-biological knowledge. The module adhered to a 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate) that was adapted for the integration of IKS.

2.6. Sample lessons:

2.6.1. Genetics (weeks 1-2):

- IKS hook: Present local chicken varieties (normal feather vs. frizzle feather) to students and pose the question: "Why do chicks occasionally exhibit feathers resembling the father, and at other times, the mother?"

- Exploration: Students gather data on feather types from their home flocks and compute simple ratios.

- Explanation: The teacher introduces Mendelian genetics through the "frizzle gene" (dominant) in contrast to normal (recessive)—drawing parallels to Mendel's pea traits while ensuring cultural relevance.

- Elaboration: Students investigate the inheritance of coat color in West African Dwarf goats (black, brown, white patterns) utilizing Punnett squares.

- Evaluation: Students articulate how traditional Igbo goat breeding practices reflect an understanding of inheritance, even in the absence of formal genetics terminology.

2.6.2. Ecology (week 3-4):

- IKS hook: Take students to a deserted fallow farm; inquire: "Which plants emerged first after the last yam harvest? Which plants are currently present?"

- Exploration: Students chart species succession across three fallow plots (1-year, 3-year, 5-year).

- Explanation: The teacher introduces concepts: pioneer species (*Chromolaena odorata*), climax community, and succession. Students compare these to the textbook model.

- Elaboration: Students conduct interviews with a local farmer regarding “how to determine when land is ready for replanting” (indicators of soil recovery).

- Evaluation: Students create a food web representing a local farm ecosystem (yam, maize, melon, goats, chickens, and predators such as snakes and kites).

2.6.3. Cellular Respiration (weeks 5-6):

- IKS hook: “Why do harvested yams and cassava generate heat during storage? Why does fermenting palm sap produce bubbles and warmth?”

- Exploration: Students observe the fermentation process of palm sap or cassava dough and document temperature variations.

- Explanation: The teacher connects observations to the cellular respiration equation (glucose → energy + CO₂ + heat).

- Elaboration: Compare respiration rates in stored yams (high respiration leading to spoilage) versus dried yam (low respiration leading to preservation), linking this to Igbo food preservation methods.

- Evaluation: Students articulate, using Igbo terminology, why freshly pounded yam after harvest has a different texture compared to aged yam.

The control group underwent traditional instruction covering the same topics but utilized textbook examples: pea plants (genetics), theoretical forest food webs (ecology), and standard yeast fermentation experiments (cellular respiration). Both groups of teachers were seasoned professionals (mean=7.2 years). The experimental teachers received two days of training focused on IKS integration and the module, while control teachers maintained their conventional teaching practices.

2.7. Procedure

The research was conducted in seven distinct phases:

Phase 1 (Week -2): Secured ethical approval and permissions from schools; selected and trained research assistants, comprising four graduate students specializing in Biology education.

Phase 2 (Week -1): Conducted the BCUT pretest for both groups, encompassing all 186 students, on a Monday to mitigate potential disruptions from sit-at-home orders. The Engagement Inventory was also administered as a baseline measure.

Phase 3 (Week 0): Educators in the experimental schools underwent a two-day training on IKS integration; meanwhile, control teachers were informed about the study procedures without revealing the alternative instructional method.

Phase 4 (Weeks 1-6): This phase marked the intervention period. The experimental group received instruction integrated with IKS, consisting of three 40-minute sessions each week, totaling 18 sessions. In contrast, the control group was taught using conventional methods, maintaining the same duration and topics but adhering to a standard textbook approach. Attendance was closely monitored, and only students with an attendance rate of 85% or higher were included in the analysis, resulting in the exclusion of three students due to absences exceeding 15%.

Phase 5 (Week 7): An immediate post-test (BCUT) and the Engagement Inventory were administered to both groups.

Phase 6 (Week 13, or six weeks following the post-test): A Delayed Retention Test (DRT) was conducted for both groups without prior notice or revision. Out of the original sample, 179 students completed all three assessments, indicating an attrition rate of 3.8%.

Phase 7 (Weeks 14-15): Twelve focus group discussions were held in the experimental schools, each comprising 6-8 students stratified by performance level (high, medium, low based on post-test results). Each focus group discussion lasted between 40 to 50 minutes, was audio-recorded, and transcribed verbatim, with Igbo phrases retained alongside their English translations.

2.8. Data Analysis

Quantitative data were examined utilizing SPSS version 28. Descriptive statistics, including means, standard deviations, and percentages, provided a summary of performance. For inferential statistics, a One-way ANCOVA was employed to enhance conceptual understanding (BCUT post-test), with pretest scores serving as a covariate to account for initial differences. An independent t-test was conducted for engagement scores, with normality assessed using the Shapiro-Wilk test ($p > 0.05$). A repeated-measures ANOVA was utilized to analyze group differences in retention, focusing on the interaction between time and group. Effect sizes were reported as partial eta squared (η^2) for the ANCOVA and Cohen's d for the t-tests. The alpha level was established at 0.05.

Qualitative data derived from focus groups were analyzed through thematic analysis as outlined by Braun and Clarke (2006). Two researchers independently coded the transcripts, identified themes, and resolved any disagreements through discussion. Representative quotes are included in the results, accompanied by pseudonyms (e.g., FG1-Male-High, indicating Focus Group 1, male student, and high performance).

2.9. Ethical Considerations

Written informed consent was secured from school principals, parents or guardians, and student assent was obtained for minors. Participation was voluntary, allowing students the option to withdraw without facing any penalties. To prevent any disruption in learning, control schools were provided with the IKS-integrated module following the conclusion of the study. The identities of schools and students were anonymized in the reporting process. Traditional knowledge shared during the instructional period was utilized with proper acknowledgment, without any claims of ownership; the study adhered to the principles of Indigenous data sovereignty, respecting the community's ownership of knowledge.

3. Results

3.1. Descriptive Statistics of Sample

Table 1 presents demographic characteristics of the 186 participating students (179 completed all phases). The groups were comparable in age, gender distribution, and baseline Biology performance.

Table 1: Demographic Characteristics of Participants

Variable	Experimental (n=94)	Control (n=92)	Total (N=186)
Gender			
Male	49 (52.1%)	49 (53.3%)	98 (52.7%)
Female	45 (47.9%)	43 (46.7%)	88 (47.3%)
Mean age (years, SD)	16.2 (1.1)	16.4 (1.2)	16.3 (1.2)
Mean pretest BCUT (% ,SD)	41.2 (12.4)	42.1 (11.8)	41.6 (12.1)
Attendance rate (% ,SD)	92.3 (5.6)	91.8 (6.1)	92.1 (5.8)

Effect of IKS Integration on Conceptual Understanding (Research Question 1; Hypothesis 1)

Descriptive: Table 2 shows pretest, immediate post-test, and adjusted post-test means for both groups. The experimental group's post-test mean (72.4%) was substantially higher than the control group (48.3%), despite equivalent pretest scores. The gain score (post-test minus pretest) was 31.2% for experimental vs. 6.2% for control.

Table 2. Mean Conceptual Understanding Scores (BCUT, maximum 85 points / percentage shown)

Group	N	Pretest Mean % (SD)	Post-test Mean % (SD)	Mean Gain (%)	Adjusted Post-test Mean % (SE)
Experimental	94	41.2 (12.4)	72.4 (9.6)	31.2	72.1 (0.9)
Control	92	42.1 (11.8)	48.3 (11.2)	6.2	48.5 (1.0)

Note: Adjusted means from ANCOVA controlling for pretest scores.

Inferential results: A one-way ANCOVA was conducted with post-test scores as dependent variable, group as fixed factor, and pretest scores as covariate. Assumptions were met: homogeneity of regression slopes ($F(1,182)=1.24, p=0.27$), normality of residuals (Shapiro-Wilk $p>0.05$), and homogeneity of variance (Levene’s $F=1.86, p=0.17$).

Table 3: ANCOVA Summary for Conceptual Understanding

Source	Sum of Squares	df	Mean Square	F	p	η^2
Corrected Model	12586.4	2	6293.2	152.9	<0.001	0.63
Intercept	1680.3	1	1680.3	40.8	<0.001	0.18
Pretest (covariate)	2842.1	1	2842.1	69.1	<0.001	0.27
Group	5891.7	1	5891.7	146.3	<0.001	0.44
Error	7541.2	183	41.2			
Total	753212.0	186				

The ANCOVA revealed a statistically significant main effect of instructional group ($F(1,183)=146.3, p<0.001, \eta^2=0.44$), indicating that IKS-integrated instruction had a large effect on conceptual understanding. Null hypothesis H_{01} was rejected.

3.2. Effect of IKS Integration on Student Engagement (Research Question 2; Hypothesis 2)

Descriptive: Table 4 presents mean engagement scores (maximum 5.0). Experimental students reported higher engagement across all three dimensions.

Table 4: Mean Engagement Inventory Scores by Group

Engagement Dimension	Experimental Mean (SD)	Control Mean (SD)	Mean Difference
Behavioral	4.3 (0.6)	2.9 (0.8)	1.4
Cognitive	4.1 (0.7)	2.7 (0.9)	1.4
Emotional	4.4 (0.5)	2.8 (0.9)	1.6
Overall	4.2 (0.6)	2.8 (0.8)	1.4

Inferential results: An independent t-test (two-tailed) was conducted. Levene’s test indicated equal variances ($F=2.10, p=0.15$). The overall engagement difference was significant: $t(184)=11.4, p<0.001$, Cohen’s $d=1.67$ (very large effect). Separate t-tests for each dimension were also significant ($p<0.001$ for all). Null hypothesis H_{02} was rejected.

3.3. Effect of IKS Integration on Long-Term Retention (Research Question 3; Hypothesis 3)

Descriptive: Six weeks after immediate post-test (with no revision or instruction), the delayed retention test (DRT) was administered. Table 5 shows that the experimental group retained significantly more content (68.1%) than the control group (39.7%). The retention decay (post-test minus delayed) was smaller for experimental (4.3% loss) than control (8.6% loss).

Table 5. Immediate and Delayed Retention Scores

Group	Immediate Post-test Mean % (SD)	Delayed Retention Mean % (SD)	Absolute Loss (%)	Relative Retention (% of post-test)
Experimental	72.4 (9.6)	68.1 (10.3)	4.3	94.1%
Control	48.3 (11.2)	39.7 (12.5)	8.6	82.2%

Inferential: A 2 (group) × 2 (time: post-test vs. delayed) repeated-measures ANOVA with Greenhouse-Geisser correction (sphericity violated, $\chi^2=4.7$, $p=0.03$) was conducted. There was a significant main effect of group ($F(1,177)=132.8$, $p<0.001$, $\eta^2=0.43$), significant main effect of time ($F(1,177)=48.2$, $p<0.001$, $\eta^2=0.21$), and a significant group × time interaction ($F(1,177)=12.9$, $p<0.001$, $\eta^2=0.07$). The interaction indicates that the control group's scores declined more steeply than the experimental group's. Null hypothesis H_{03} was rejected.

3.4. Qualitative Findings: Students' Perceptions of IKS-Integrated Biology (Research Question 4)

Thematic analysis of 12 focus group discussions (n=78 students, experimental schools) yielded five major themes.

3.4.1. Theme 1: "It connects school to my real life" – Meaningfulness and relevance

Overwhelmingly, students reported that IKS integration made Biology "feel real" rather than "just for exams." A high-performing female student in Enugu explained:

"Before, when we learned about genetics, I only thought about Mendel's peas. I have never planted peas. But when we talked about our local chickens; the ones with frizzle feathers; I suddenly understood. I went home and asked my mother: 'If you want more frizzle chicks, which rooster you should choose?' She told me. That was segregation. I will never forget." (FG3-Enugu-Female-High)

Similarly, a male student in Anambra noted: "Cellular respiration was a mystery. Glucose, ATP, and mitochondria; these are like English words. But when we smelled fermenting palm sap and felt the heat, I said: Ah! That heat is energy. The sugar is being turned to energy. The teacher said 'yes.' Why has no one taught us this way before?" (FG5-Anambra-Male-Medium)

3.4.2. Theme 2: "It makes hard things easier" – Scaffolding abstract concepts

Many students explicitly compared the IKS approach favourably to previous rote learning. A low-performing student (based on pretest) said:

"I always failed ecology. Food web? I could not remember who eats who in the textbook diagram. But when we went to the farm and saw the real things; yam beetles eaten by lizards, lizards eaten by snakes, snakes eaten by kites, I drew it myself. In the exam, I closed my eyes and saw that farm. I passed for the first time." (FG7-Enugu-Male-Low)

Another student elaborated: "The teacher called the local names first: *olugbu* (bitter leaf), *nchanwu* (scent leaf), *uda*, then told us the scientific names. The Latin names are still hard, but now I have a hook to hang them on" (FG2-Anambra-Female-Medium).

3.4.3. Theme 3: "I felt proud, not ashamed" – Cultural validation and identity

A recurring theme was that IKS integration validated knowledge students had from home, which previously was ignored or implicitly devalued. A female student shared:

"My grandmother is a healer. I know many plants and what they cure. But in Biology class before, I never spoke about that, I felt it was 'not science.' But when the teacher asked us to share what our families use bitter leaf for, everyone had something to say. For the first time, I felt my grandmother's knowledge was respected. That made me want to learn more." (FG1-Anambra-Female-High)

A male student added: "Some of my friends thought science was for 'bookish' people only, not farmers' children. But when we studied ecology using our fathers' fallow farms, they saw that farmers are scientists. They just use different words" (FG9-Enugu-Male-Medium).

3.4.4. Theme 4: “It should be this way always” – Demand for curriculum change

Almost all focus groups spontaneously expressed that the IKS approach should be standard. A student in Anambra stated forcefully: “Why do we have to wait for a research study? This should be how Biology is taught in every school. We are Igbo. We live among plants and animals. We have names for everything. The government should make a book with our own examples.” (FG11-Anambra-Male-High)

Another student raised a practical point: “Even the teachers liked it. Our teacher said he learned new things from the elders we interviewed. So it is not just for students, teachers also did not know the science behind the local knowledge” (FG4-Enugu-Female-Medium).

3.4.5. Theme 5: “Some things were still hard” – Limitations and challenges

Students also identified limitations. The molecular aspects (e.g., glycolysis steps in cellular respiration) remained difficult even with IKS scaffolding. A high-achieving student noted: “I understood that fermentation makes energy, but the specific steps, glucose to pyruvate to ATP—that was still memorization. The local examples helped me want to learn it, but it did not make it simple.” (FG6-Anambra-Male-High)

Some students also noted that urban students or those whose families had moved away from traditional practices might have less IKS background. “If your parents are both bankers and you never visited a village farm, the local examples might be as strange as the textbook examples,” observed one student (FG8-Enugu-Female-Medium). Teachers in the experimental group (interviewed separately, data not systematically analyzed) echoed that time constraints made it difficult to cover both IKS content and the full syllabus.

To summarize: (1) IKS-integrated instruction produced significantly higher conceptual understanding (72.4% vs. 48.3%, large effect $\eta^2=0.44$); (2) engagement was substantially higher in the IKS group (4.2 vs. 2.8 out of 5, very large effect $d=1.67$); (3) retention was better preserved in the IKS group (loss of only 4.3% vs. 8.6% in control); (4) students overwhelmingly perceived the IKS approach as meaningful, culturally validating, and effective, while noting that molecular-level details remained challenging. All null hypotheses were rejected.

4. Discussion

This research examined the impact of incorporating Igbo ethno-biological knowledge and Indigenous Knowledge Systems into senior secondary Biology education on students' conceptual comprehension, engagement, and retention of challenging subjects (genetics, ecology, cellular respiration) in comparison to traditional teaching methods. The results strongly support the notion that the integration of IKS leads to significant, statistically relevant, and practically beneficial outcomes. The subsequent discussion addresses the findings in the context of the theoretical framework, relevant literature, educational implications, limitations, and potential avenues for future research. The observation that students in the experimental group achieved an adjusted score of 72.4% compared to 48.3% for the control group on the BCUT indicates a relative improvement of 50% (24.1 percentage points). An effect size of $\eta^2=0.44$ suggests that nearly half of the variance in post-test scores can be attributed to the instructional method rather than to individual differences or prior knowledge. This represents a substantial effect in the realm of educational research (Hattie, 2012). The increase of 31.2% from pretest scores in the experimental group (as opposed to 6.2% in the control group) implies that the integration of IKS does not simply serve as a “cultural embellishment” to the instruction but significantly transforms the learning pathway.

What accounts for the effectiveness of IKS integration in enhancing conceptual understanding? The socio-cultural constructivist perspective (Vygotsky, 1978) provides insight: the IKS examples (local chicken genetics, fallow farm succession, palm sap fermentation) act as “cultural tools” that facilitate the transition from everyday concepts to scientific concepts. Within Vygotsky's framework, everyday concepts (spontaneous, context-specific, and rich in experience) must converge with scientific concepts (abstract, systematic, and decontextualized) within the zone of proximal

development. The IKS examples serve as a bridge: students already have a solid foundation of everyday concepts regarding inheritance in local animals, succession on fallow land, and fermentation in food preservation.

The educator's responsibility is to associate formal terminology (allele, pioneer species, glycolysis) with these pre-existing cognitive frameworks. In the control condition, Western examples (peas, hypothetical forests, yeast from a packet) do not possess this pre-existing framework; thus, students are required to develop both the concept and its exemplar concurrently, creating a dual cognitive burden that hinders learning (Sweller, 1988). This observation is consistent with Ogunniyi's (2016) research in South Africa, which demonstrated that the integration of Indigenous Knowledge Systems (IKS) in science enhanced performance on standardized assessments, as well as with Mbajorgu and Ali's (2003) earlier study in Nigeria that indicated culturally relevant instruction improved comprehension in chemistry. Nevertheless, the current study extends beyond prior research by evaluating retention (six weeks later) and engagement, while concentrating on topics identified as "difficult" by WAEC.

An unexpected yet significant finding is that the IKS group's performance on short-answer application questions (mean 68%) was markedly superior to that of the control group (mean 32%), particularly in comparison to multiple-choice items (experimental 75% vs. control 53%). This indicates that the integration of IKS notably enhances the transfer and application of knowledge—the capacity to utilize biological concepts in unfamiliar contexts. A student who has learned Mendelian genetics through local chickens can apply analogical reasoning to a test question regarding inheritance in goats, whereas a student who learned through peas may struggle. This has profound implications for WAEC/NECO examination outcomes, where application questions have historically yielded the lowest scores (WAEC, 2022).

The overall difference in engagement (4.2 vs. 2.8 on a 5-point scale, Cohen's $d=1.67$) is remarkably substantial. For reference, Hattie (2012) meta-analyses indicate that a d of 0.4 is a typical effect size for educational interventions. A d of 1.67 suggests that the integration of IKS has resulted in engagement levels that are practically transformative. Importantly, the emotional engagement aspect (4.4 vs. 2.8) exhibited the most significant difference. Qualitative data elucidate this: students expressed feelings of being "proud" instead of "ashamed," "interested" rather than "bored," and "connected" rather than "alienated." This observation directly reinforces the principles of culturally relevant pedagogy (Ladson-Billings, 1995). When students recognize their home knowledge, such as their grandmothers' healing practices and their fathers' agricultural wisdom, as valid scientific knowledge, the emotional barriers to learning science diminish. The qualitative theme "I felt proud, not ashamed" is especially significant: numerous students had absorbed the colonial narrative that Indigenous knowledge is deemed "unscientific" or "backward" (Aikenhead, 2006). By framing Indigenous Knowledge Systems (IKS) as a legitimate pathway to scientific concepts, the intervention facilitated a psychological reparation, reinstating students' epistemic confidence.

Moreover, the cognitive engagement dimension (4.1 vs. 2.7) suggests that students were engaging in deeper thought about Biology beyond the classroom. Many participants in the focus groups reported conversations about Biology with their parents, grandparents, and local farmers, creating a flow of home-school knowledge that traditional instruction often suppresses (as parents perceive their knowledge as not being "school knowledge"). One female student remarked: "I inquired with my grandmother about bitter leaf and malaria. She demonstrated how she prepares it. Subsequently, I read in my textbook about alkaloids and their antimalarial properties. Now I am teaching my grandmother the 'science words' for what she already understands." This intergenerational exchange of knowledge, stimulated by the integration of IKS, represents a significant educational achievement beyond mere test scores.

The enhanced retention observed in the experimental group (with the experimental group losing only 4.3% over six weeks compared to 8.6% for the control group; relative retention rates of 94% vs. 82%) aligns with cognitive psychology findings regarding meaningful learning (Ausubel, 1968). When information is linked to a pre-existing, comprehensive cognitive schema (the student's IKS framework), it is encoded in a more detailed manner and can be retrieved with greater ease. Conversely, information learned by rote (characteristic of the control condition, where students memorized definitions of alleles and food webs without forming deep connections) tends to decay

swiftly. The notable group \times time interaction ($F=12.9, p<0.001$) suggests that the forgetting curve for the experimental group was less steep. Practically, this implies that when students revisit Biology in subsequent semesters or prepare for external examinations, learning that integrates IKS results in more enduring knowledge. Numerous Nigerian students resort to “cramming” for WASSCE and quickly forget; this study indicates that instruction rooted in cultural context fosters knowledge retention. However, even the experimental group experienced some knowledge loss (4.3%). The intricate details of cellular respiration remained difficult, as qualitatively observed. This indicates that while IKS scaffolding aids in grasping abstract concepts, it does not eliminate the inherent challenges associated with biochemical pathways. Continuous exposure, visual aids, and further practice remain essential.

This study offers three theoretical contributions. Firstly, it operationalizes Jegede’s (1995) collateral learning theory by illustrating that “harmonious collateral learning” (the integration of IKS and Western science) leads to superior outcomes compared to “parallel collateral learning” (keeping the two separate) or “destructive collateral learning” (where school science undermines IKS). The experimental condition successfully harmonized the two knowledge systems, whereas the control condition inadvertently perpetuated destructive collateral learning by completely disregarding IKS. Secondly, it broadens Vygotskian sociocultural theory to the particular realm of Indigenous science education. The research indicates that “cultural tools” are not limited to tangible items (such as calculators or microscopes) but can also be conceptual, encompassing the structured knowledge systems that students bring from their homes. Educators can purposefully utilize these tools as scaffolding.

Furthermore, it contests the deficit models that portray African students as “lacking” in scientific knowledge. In reality, these students possess a wealth of ethno-biological understanding; the shortcoming lies within the curriculum that does not acknowledge or utilize this knowledge. As one student expressed with frustration: “Why did we wait for a research study? This should be how Biology is taught.” The issue does not reside with the student or their culture; rather, it is rooted in the design of the pedagogy.

4.1. Practical and Policy Implications

For curriculum developers (NERDC): The results provide strong evidence in favor of creating a formal ethno-biology module for senior secondary Biology, not merely as an additional “cultural studies” component but as a cohesive element woven throughout the syllabus. Curriculum designers should pinpoint Igbo (or regional) ethno-biological equivalents for each significant topic (taxonomy, genetics, ecology, physiology, reproduction). For instance: taxonomy can be taught through folk classification in conjunction with Linnaean methods; genetics can be explored via local livestock and crop varieties; ecology can be examined through fallow succession, sacred groves, and indigenous agricultural practices; physiology can be illustrated through the effects of ethno-medicinal plants. This approach would not supplant Western biology but rather enhance it, in accordance with UNESCO’s (2018) advocacy for “two-eyed seeing” (Etuaptmumk): the ability to perceive through both Indigenous and Western perspectives.

For teacher education: Both pre-service and in-service training must encompass practical methodologies for integrating Indigenous Knowledge Systems (IKS). The two-day training conducted in this study proved adequate to yield significant outcomes, yet the establishment of ongoing professional learning communities would be more beneficial. Teacher education institutions (such as Colleges of Education and Faculties of Education) ought to embed courses on “Ethno-biology and Culturally Relevant Science Teaching” within their curricula. An example module could involve teachers learning to perform community ethnobotanical surveys, engaging local elders as resource persons, and crafting lessons that transition from IKS to scientific abstraction.

For WAEC and NECO: Examination authorities ought to contemplate the inclusion of items that are rooted in Indigenous Knowledge Systems (IKS) contexts, not merely as “alternative” easier questions, but as equally challenging items that evaluate the same scientific principles through examples that are culturally relevant. A genetics question concerning the inheritance of coat color in West African Dwarf goats is not less challenging than a question about pea plants; it necessitates the same level of scientific reasoning but is more relatable for Nigerian students. WAEC has initiated this transition (in 2022, a question regarding cowpea weevil genetics was introduced), yet a more

systematic transformation is essential. Reforming examinations would convey to educators that the integration of IKS is esteemed.

For school-level practice: Educators can promptly implement low-cost IKS strategies: (1) Initiate each topic with a discussion titled "What do we know from home?"; (2) Substitute textbook examples with local species or animals; (3) Task students with interviewing elders to gather insights on indigenous biological knowledge; (4) Utilize school gardens and local farms as practical laboratories; (5) Invite traditional healers or farmers to serve as guest speakers. These strategies necessitate no costly resources, only a change in pedagogical approach.

This study has several limitations. Firstly, the quasi-experimental design (non-random assignment to condition) constrains causal inferences, although pretest equivalence and ANCOVA enhance internal validity. Secondly, the research was conducted in two states (Enugu, Anambra) within predominantly rural or peri-urban environments; thus, the findings may not be applicable to urban schools where students may have weaker direct connections to traditional IKS (although qualitative data indicate that even urban students maintain familial ties). Thirdly, the duration of the intervention was relatively brief (6 weeks); the long-term impacts (e.g., retention over one year, performance in WASSCE) remain uncertain. Fourthly, the effects of teachers were not entirely controlled; while both groups were taught by experienced educators, the teachers in the experimental group may have exhibited greater motivation. Lastly, the study concentrated on only three topics; further investigation into IKS integration for additional subjects (e.g., reproduction, evolution) is warranted.

Future investigations should: (a) implement a multi-regional randomized controlled trial across South-East, South-South, and South-West regions to compare various IKS traditions; (b) evaluate actual WASSCE performance as a measurable outcome; (c) analyze the "dosage effect" to determine the optimal level of IKS integration; (d) investigate digital ethno-biology resources, such as mobile applications featuring local plant databases; (e) examine educators' beliefs and their resistance to the integration of IKS; (f) assess the influence on students' attitudes towards STEM careers; and (g) evaluate whether the integration of IKS contributes to narrowing the urban-rural achievement gap, as rural students may gain more due to their increased exposure to IKS.

A methodological constraint is that the BCUT and the delayed test utilized the same format, albeit with rewording. While practice effects cannot be completely dismissed, the minimal gain observed in the control group (6.2%) indicates that familiarity with the test format alone does not account for the results. Future research could consider employing parallel forms. Some critics contend that the integration of IKS may "dilute" scientific rigor or foster relativism, suggesting that all knowledge systems hold equal validity. This study counters that perspective. IKS is not portrayed as being on par with Western science across all domains; for instance, IKS does not elucidate ATP synthesis at the molecular level. Instead, IKS functions as a pedagogical bridge, providing a culturally relevant starting point from which students can progress to established scientific concepts. The ultimate goal remains the standard Biology curriculum, rather than a distinct "indigenous biology." This methodology honors both knowledge systems while maintaining their distinctions.

Another critique is that the integration of Indigenous Knowledge Systems (IKS) may lead to the essentialization or romanticization of traditional knowledge, presuming that all Igbo students inherently possess it. However, this is not the case, as some have pointed out that urban students may lack a background in IKS. The appropriate approach is not to assume that all students have a universal proficiency in IKS, but rather to incorporate IKS into the curriculum as one would with any other subject: some students may arrive with prior knowledge, while others will acquire it during the lesson. Educators should frame IKS examples by stating, "Here is one way that people in this region understand nature," instead of asserting, "All Igbo people know this." This method helps to prevent stereotyping while still utilizing the cultural significance of IKS.

5. Conclusion

This research presents compelling empirical evidence indicating that the incorporation of Igbo ethno-biological knowledge alongside Indigenous Knowledge Systems into senior secondary Biology education significantly enhances students' conceptual comprehension, engagement, and long-term retention of challenging subjects when compared to traditional teaching methods. Students

participating in the IKS-integrated cohort achieved scores that were 50% higher on tests assessing conceptual understanding, reported markedly increased levels of engagement, and demonstrated superior knowledge retention six weeks post-instruction. Qualitative findings indicated that students perceived the integration of IKS as meaningful, culturally affirming, and effective in rendering abstract concepts more accessible. The theoretical implication suggests that science education within post-colonial frameworks must transcend deficit models and adopt a paradigm of 'harmonious collateral learning,' wherein Indigenous and Western knowledge systems are intentionally interconnected rather than maintained in isolation or opposition. The practical implication is pressing: NERDC, teacher training institutions, WAEC, and NECO should formulate and execute formal strategies for the integration of ethno-biology. This issue transcends mere cultural sensitivity; it pertains to pedagogical efficacy and educational equity. For an extended period, Nigerian students have been instructed in Biology as though their grandmothers' insights regarding bitter leaf, their fathers' knowledge of fallow farming, and their communities' connections to local biodiversity were inconsequential. This study demonstrates the contrary: that locally-sourced knowledge serves as the most robust foundation for scientific abstraction. It is imperative for Nigerian Biology education to turn its focus inward.

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