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Beyond Preservation: Intergenerational Transmission of Indigenous Food Knowledge through Chemistry Education—An African Intangible Cultural Heritage Framework

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Abstract

Indigenous ways of food processing demonstrate chemicals knowledge and practical abilities. However, inclusion of these ways of processing food in chemistry curriculum may not help in retention of the traditional knowledge. This study examines integration of certain cultural values with achievement of specific learning goals (the African Indigenous Food Knowledge Transmission through Chemistry Education Model (AIFKT-CEM). The study focuses on 360 learners in 24 school clusters in south eastern Nigeria. The study assessed the learners' knowledge on food and chemicals and the differences between the groups integrated indigenous food knowledge in Chemistry (IFK-CE) and traditional teaching (control) over a period of time. Gains in the control group in food-chemistry literacy were 2.51 points in literacy, 1.55 in inquiry, 2.20 in documentation and 2.10 in communication. The IFK-CE group recorded knowledge-sharing events and recipient recall of the knowledge transferred for 71.7% of the learners and 45.6% of the learners respectively. The differences should not be misinterpreted as causal effects. This study provides evidence to support the need to analyse chemical knowledge and inquiry in an educational context as well as document and communicate the findings. Finally, this study promotes an integrated approach for the teaching of Chemistry to protect cultural values and food safety.

Keywords: Food Knowledge Systems, Chemistry Education, Intangible Cultural Heritage, Learning, Pedagogy, Fermentation, Evaluation, Nigeria

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1. INTRODUCTION

The emphasis on classroom science often ignores the material processes underlying the content, limiting explanations to abstractions and relying on correct science practices to assess understanding. Chemistry education focuses on features such as fermentation, oxidation, acidity, moisture and preservation. However, living African food systems employ these elements to preserve food and nurture familiarity with the use of experience, practice, and intergenerational collaboration. Material practices and vernacular classifications are used to evaluate the quality of a food. For example, a student may identify a fermented food or understand the process by which it was made without understanding the acceptable standards for determining its quality. Similarly, a student may learn an etch process to preserve food but not understand the conditions under which the food may be unsafe.

A line is drawn between science and culture; science practices are taught and assessed independently of cultural knowledge. This creates a dual curriculum where cultural knowledge is either completely omitted or restricted to an illustrative sample (Oladejo et al., 2022; Aina, 2025).

The Convention recognises living heritage as the know-how and skills, transmitted via nurturing practices, between and among individuals, groups and communities. For heritage protection, the Convention recommends incorporating living heritage into the educating and training practices at various levels. However, the Convention clearly states that creating an archive does not guarantee the protection of a practice (UNESCO, 2003). In educational research, this is significant. In effect, there is a distinction between recording, or documenting, how a practice is carried out, and demonstrating that the members of the community are able to practice it and maintain its continuity. UNESCO's guidelines state that educating the public about the importance of a heritage, and involving community members in the educating process, is vital. The community members should decide what is taught to the public (UNESCO, n.d.-a).

Nigeria, particularly, the variety of fermented food practices, serves as another context. Several studies are available that cover challenges of process control of indigenous Nigerian fermented food products, as well as the safety of such food products (Dike et al., 2022). Numerous methods are available for the transformations, fermentations and preservations of perishable food products. In effect, not all practices of a culture can be expressed via a single food practice or a single food product. This is particularly true for food products with a prolonged shelf life (SAC, 2020).

Methods grounded in Nigerian cultural contexts demonstrate success in the context of teaching and learning nuclear chemistry. In a Lagos-based study, Oladejo et al. (2022) demonstrated how the application of a culturo-technical approach enhanced the achievement of students of nuclear chemistry. Eze, Okere, and Okorafor (2025) focused on the use of local resources and practices in secondary-level chemistry in Abia State. The above-mentioned studies provide evidence to support the adaptation of contextualisation to teaching. There are varying content, materials, duration, and methods of teaching in different locations; however, such factors do not necessarily prove an individual's capacity to transmit traditional food knowledge and ensure its continued presence across generations. It is imperative that a deeper inference be drawn, especially when considering traditional and scientific knowledge.

The African Indigenous Food Knowledge Transmission Through Chemistry Education Model (AIFKT-CEM) is developed to address these gaps, and provides theoretical and methodological frameworks. The model has an educational and cultural heritage dimension. Additionally, it defines the parameters between teaching nuclear chemistry and safeguarding traditional knowledge. Through case studies conducted in different parts of Africa, this model will strengthen the grounds for further exploration of the intersection between scientific and traditional means for teaching and preserving nuclear

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knowledge.

2. LITERATURE REVIEW

2.1. Indigenous food practices as local knowledges of chemistry

transforming food through local practices of heating, cooling, and/or combining. The chemical changes occurring during the fermentation of cassava, for instance, include breakdown of starch and/or other complex carbohydrates, changes in acidity and/or moisture content, and/or the growth and/or multiplication of microorganisms, etc. Knowledge about such changes as well as the sensory judgement about degree of changes and acceptability of the end product is also of educational importance. A good deal of research has established the importance of hygiene and quality control in the production of traditionally fermented foods. Iwuoha and Eke (1996), for instance, reviewed types and processes of fermentation of tubers, cereals and legumes in various communities in Nigeria. Achi and Akomas (2006) studied variances in fufu processing and the use of alternative fermentation. Recent studies have employed modern methods and/or technologies to study microbiology of cassava-based products (Dike et al. 2022). These studies have provided a foundation for chemical research and analysis of school samples.

It is important to accurately categorise or type claims. Sensory judgement of end-product acceptability is relatively easy to teach. Establishing safety of the end product is laboratory work and is beyond the scope of school curriculum. When an end product of a traditional food process is found to be unsafe, this does not mean that such a food process loses its cultural and/or traditional significance. This has been articulated and described elsewhere (Zidny, Sjöström and Eilks 2020, Smith, Avraamidou and Adams 2022).

2.2. Chemistry and the Transfer of Learning

Cultivating exemplary practices helps augment the connections between the desired outcomes and expectations of chemistry learning, students' lived realities, and their sense of identity and social-relational environments. In the field of science education, the inclusion of Indigenous knowledge has the potential to strengthen the engagement and participation of students in epistemic (e.g. scientific) activities and has the potential to positively influence the criticism and integration of local knowledge in the field of science (e.g. Jin, 2021). Decolonising science education through the incorporation of African Indigenous Knowledge Systems (African IKSs) has the potential to positively affect the decolonisation of science education; however, misconceptions and erroneous assumptions can persist amongst students, including a lack of the ability to interrogate broader scientific generalisations and examine social justice and power (Aina, 2022; Ngugi, 2021).

The African Science Literacy and Learning Network (ASLLN, 2022) identifies contextualisation, participation, and engagement as levers through which the science learning outcome may be realised. Nonetheless, reliance on learner-centred strategies and activities does not guarantee that students have learned the desired concepts or skills (Furtak, Hanson and Zachrajac, 2012; Lazonder & Harmsen, 2016; Freeman et al., 2014). The ten week instruct Debrief and reflect (IDR) sequence of the current study provided a framework for students to work with culturally pertinent research tools and constructs, incorporate and interpret different chemistry viewpoints, all while learning to operate within the norms and ethics of scientific inquiry and practice (Oladejo et al., 2022; Mahaffy et al., 2019).

2.3. Living heritage: Participation and community control

Preserving living heritage means ensuring the continuity of knowledge and practice through practice and recreation by concerned communities. Communities have an important role to play in determining how heritage is preserved. It concerns communal knowledge and practice. From a Safeguarding perspective, it

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is legitimate for communities to determine what can be recorded, regardless of the school's interest. Based on the ethical principles of UNESCO (UNESCO, n.d.-b), it means that if concerns of a community or customary authority are taken into consideration and honoured, community governance is a core element of the programme, and not an added Safeguarding consideration after completion of the programme.

In any case, decisions regarding communal heritage should not be skewed in favour of the school. If knowledge and practices about communal heritage are recorded by the school, older members of the community may not have the opportunity to determine how their knowledge is documented and may not be able to control how the knowledge is used. This may also be the case for educators who may lose control over how materials are used and who have the privilege of publishing the materials. In order to promote scholarly practices, school directors and other partners should assist in determining the terms of access and use of communal heritage and estate.

2.4 Scientific literacy, inquiry, and construct-related validity

Four related, but distinct, constructs are articulated in the project. Chemical Food Literacy focuses on food-related chemical concepts, and encompasses the abilities to explain and understand the interpretation and transfer of chemical concepts. Inquiry competence encompasses the understanding of constructs related to the scientific method including the identification of variables and their measurement. Documentation competence encompasses the ability to record and justify the decision to omit certain procedure details. Knowledge Communication encompasses the student's responsiveness to community feedback regarding the quality of the explanation. All of the above-mentioned constructs have been operationally defined. It has also been operationally defined what would constitute an actual instance of the knowledge communication. Evidence of the inferred instance would be documentation of an actual knowledge communication and delayed recall of the communicated knowledge by the recipient.

2.5. Conceptual contribution: AIFKT-CEM

AIFKT-CEM allows for the interrelation of community-based food knowledge and ethical dimension of research and learning as it relates to chemical sciences and copyrights, rather than privilege chemical sciences to be the final adjudicator on all other cultural knowledges. Teachers strategically integrate community-recognised practices, and orient learners to recognise limits, appreciate needs and catalyse action to encounter community knowledge and practices, and scientific inquiry. Outcomes are assessed along the academic and cultural domains. Depending on the context, the willingness of knowledge keepers to share their knowledge, and the extent to which the school, community and family collaborate, the results of this strategy may facilitate community food security and sustainability.

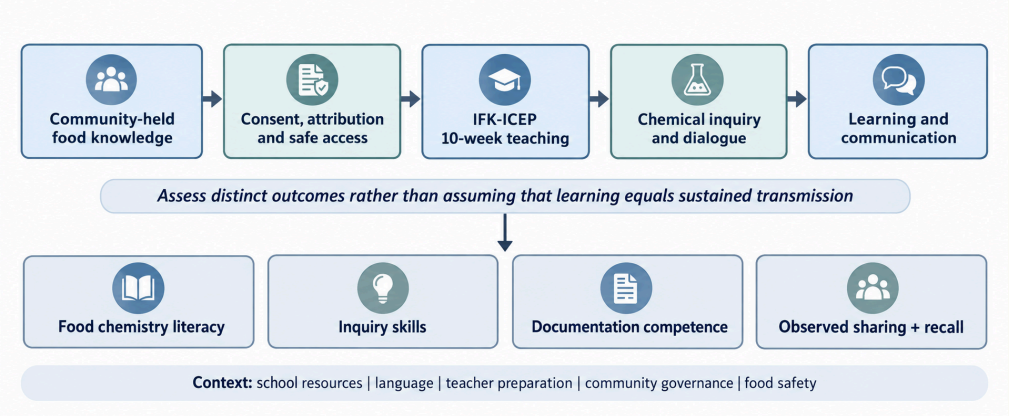


Figure 1. Community authority, instructional mechanisms and distinct assessment domains

Source: Conceptual synthesis informed by UNESCO (2003) and culturally responsive science education scholarship.

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Cultural responsive science education positions the community to be the authority in various aspects of science instruction including integration, and assessment. The model does not assert that involving the community to a higher degree will lead to a higher level of chemistry understanding. The closer a community is to achieving food justice, the more restricted materials may be for instruction. Rival or competing explanations for outcomes are of greater research importance.

3. METHOD

3.1. Review of architecture and evaluability

The study design is comparative and repetitive and uses a critical integration of published work on indigenous food processing in Nigeria, culturally responsive teaching of chemistry, and assessment in the context of Chemistry teaching and Learning, and safeguarding of living heritage. It adopts a lecturer-centred approach. Quantitative data were collected from 24 schools and 360 learners, in two teaching condition, using baseline and post-test, and delayed checks. Researchers organised the data for one school and one learner over the seven-day period. The researcher obtained informed consent from participants. The research focused on 'transparent' or 'clear' description and comparison. The interpretation was grounded in the field of evaluation and culturally responsive education. Even though transcripts of interviews were not available, researchers analysed data, structure and processes employed using techniques of thematic analysis. The analysis was informed by thesis that the field of education is interpreted culturally (Braun and Clarke, 2022).

Table 1. Related elements of the evaluation framework

Workstream	Core activity	Evidence required	Critical safeguard
Community knowledge	Identify accessible food practices and knowledge holders	Consent-governed inventory; agreed access categories	Community authority and right to withhold
Programme validation	Review ten-week lessons and inquiry tasks	Expert ratings; pilot comprehension; teacher preparation	Equal curricular coverage and safe experiments
School comparison	Two-arm, baseline/post/delayed assessment	Authenticated school registers and assessed scripts	Allocation transparency and cluster-aware analysis
Knowledge transmission	Approved sharing, revision and recipient follow-up	Observed event, feedback and delayed recipient recall	Attribution, reciprocity and restriction compliance

3.2 School structure, comparators and exposure to instruction

The study involved 24 schools (12 from each of the five states: Abia, Anambra, Ebonyi, Enugu and Imo). Each state school had 15 learners; therefore 360 learner records in total (180 in each group). The 24 schools represented the three main settlements (urban, peri-urban and rural). Since conditions of teaching were at the school level, learners in the same school were not statistically independent. Allocation of school to conditions was not truly random.

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Table 2. Instructional conditions and constraints on comparison

Dimension	IFK-ICEP	Conventional chemistry	Interpretive condition
Core chemistry	Acidity, oxidation, moisture, processing and measurement	Same disciplinary concepts	Content and planned minutes balanced
Practical work	Guided experiments connected to approved local examples	Guided experiments in conventional contexts	Comparable practical exposure
Community participation	Authorised contributions from knowledge holders	No structured heritage component	Consent and exposure documented
Reflective tasks	Scientific–cultural comparison and contextual reasoning	Conventional explanation and problem solving	Unfamiliar assessment prompts
Assessment occasions	Baseline, immediate and delayed	Baseline, immediate and delayed	Common scales and masked marking
Principal contamination risk	Transfer of community teaching materials	Unrecorded heritage discussion	School-level fidelity monitoring

3.3. Community co-governance and knowledge selection

The starting point for deciding whether to teach something is agreeing that the practice is teachable. While examples such as garri, fufu, and ogi, and other legume fermentation, are readily available for teaching, participation in research is not. Permissible examples and description of these are determined by a community. They also set rules concerning recording andunder what circumstances examples can be removed. Examples not allowed for teaching are not disclosed to the public. Retaining this knowledge allows the community to make decisions concerning their interests and ruling, rather than fusing these two functions (UNESCO, 2003; UNESCO, n.d.-b).

In the food chemistry unit, processes suitable for students to observe and interpret are emphasised. School activities can help students design experiments and/or observe comparisons involving chemical processes such as colour changes and other school specimens (i.e.,Comparison of grain specimens). A school specimen may be used to examine and interpret the presence of a school-based pathogenic organism. It is important to note, however, that the appearance of a specimen (i.e., cassava) may not indicate the absence of a pathogen. The same consideration applies to other fermented foods, as it is possible to have diverse microorganisms in such foods (Dike et al., 2022).

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Table 3. Curricular examples and evidence boundaries

Learning context	Chemical question	Assessment task	Safety and governance boundary
Cassava fermentation	How do acidity and processing conditions relate?	Interpret provided pH series and procedural descriptions	No consumption; no claim of cyanogen removal
Cereal fermentation	What changes can be inferred from acidity measurements?	Distinguish pH, titratable acidity and microbial inference	No culturing of unknown organisms
Legume condiments	What chemical and biological transformations are plausible?	Compare grounded explanations with uncertainty	Community permission for recipes and attributions
Food drying	How does water loss differ from full preservation?	Mass-balance and storage-limitation calculation	No claim that drying guarantees safety
Procedure documentation	What evidence is essential for faithful explanation?	Authorised steps, cultural meaning and source attribution	Restrict publication by consent terms

3.4. Ten-week curriculum and intervention fidelity

This instructional sequence spanned ten weeks in each of the 24 participating schools, amounting to 240 school-week observations overall. Weekly topics included community orientation and access restrictions; food composition; processing of cassava; fermentation and the pH of cereals; the science of measurement and moisture; preservation and comparative interpretations of the chemistry; documentation and attribution of sources; communication with the community and assessment with feedback. Each of the 75 minute sessions was analysed with respect to the delivered instruction, the practice, the extent of learning related to heritage, the participation of the knowledge holders, safety exceptions, and fidelity. A delayed assessment was considered a measurement occasion on the following week, rather than an additional instructional week.

Fidelity was defined using the exposure and the process indicators, rather than the completion of the timetable as an indication of appropriate teaching. The minutes relating to heritage and the knowledge holders indicate the extent of curricular differentiation that existed, while safety exceptions remain as a separate indicator. A restriction on the disclosure of the customary knowledge of the community should not be considered as inadequate teaching. As UNESCO (2003) and their ethical advice state, restrictions that the community decides on regarding access and attribution are central to legitimate heritage education (UNESCO, n.d.-b).

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3.5. Measurement instruments, scoring and validation

Four outcome measures were assessed. The maximum score for the Food Chemistry Literacy Test (FCLT) was 40. The Chemistry Inquiry Skills (CIS) scale was made up of eight elements, each scored from 0 to 4, resulting in a maximum score of 32. The Indigenous Food Knowledge Documentation Competence (IFKDC) scale measured six elements, each scored from 0 to 4, with a maximum of 24. Knowledge Communication Competence (KCC) was measured on a 20-point scale. Each construct was measured at baseline, immediate post-test and at the delayed follow-up. The totals for the inquiry and documentation components were aligned with the respective learner-level scores. Communication competence was evaluated independently of whether an authorised sharing event occurred and of whether the recipient exhibited delayed recall in order to prevent the confusion of the concept of communication with the observable act of sharing.

Table 4. Measurement specification and validity priorities

Construct	Scale	Evidence source	Principal validity risk
Food chemistry literacy	0–40	Unfamiliar explanatory chemistry tasks	Language complexity and item alignment
Chemistry inquiry skills	8 domains × 0–4 = 32	Observed inquiry and structured records	Procedural skill versus conceptual recall
Documentation competence	6 domains × 0–4 = 24	Approved procedures and attributed documentation	Scoring of restricted information as missing
Knowledge communication	0–20	Recipient-facing explanation and feedback	Self-presentation mistaken for comprehension
Knowledge-sharing event	0/1	Directly documented authorised exchange	Intentions mistaken for activity
Delayed recipient recall	0/1	Recipient demonstration or recall after delay	Immediate exposure mistaken for persistence

To meet the needs of construct validity, total scores are not sufficient. Alongside the review by experts in the relevant discipline and in culture, constructs are based on a number of other safeguards, such as cognitive interviews with students. Multilingual responses should be assessed for conceptual correctness rather than criticised solely for lack of English. In addition, scoring rubrics for documentation should not penalize culturally appropriate withholding of information. It is inappropriate for learners to receive a lower score for adhering to the established boundaries concerning the recording or dissemination of community knowledge (UNESCO, n.d.-b; Smith, Avraamidou and Adams, 2022). This information is intended to narrow the boundaries of score interpretation and validate the measuring instrument.

3.6. Intergenerational transmission as an independent outcome

Intergenerational transmission was defined using three separate observations: a sanctioned knowledge dissemination occasion, a delayed recipient recall indicator, and recipient feedback pertaining to a documented event. The researcher indicated that verbal consent was obtained. The roles of knowledge

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holders and knowledge recipients were documented to differentiate participation from communication outcomes. A documented event indicates that knowledge was disseminated, while the delayed recall indicator provides slight evidence that the communicated knowledge was retained over the assessment period; neither of these indicators, taken independently, provides evidence of the long-term transmission of community practice. This distinction agrees with UNESCO's description of living heritage as community-acknowledged knowledge that is sustained through ongoing transmission and re-creation (UNESCO, 2003; UNESCO, n.d.-a).

The proportions of events and recalls were computed separately for each of the instructional conditions, and recalls were assessed among the records in which a sharing event took place. The coding structure required a prior sharing event for positive delayed recall; feedback was recorded as zero in the absence of an event. These logical constructs maintained the boundary between the educational reach and the understanding of the recipient. They do not, however, provide evidence of the depth, reciprocity, or the long-term cultural significance of any particular exchange.

3.7. Statistical analysis and data integrity

To summarize learner outcomes, means with standard deviations, were computed across conditions and sessions. The baseline-to-post-test gain was computed as the difference between post-test and baseline, and the change from post-test to the delayed measure was considered. The gain mean was described as the retention of the gain (post-test mean – baseline mean) and was expressed as a percentage of the delayed mean. To obtain a gain mean difference, means or gain corresponding to the conventional condition and the IFK-ICEP condition were subtracted. The exposure to the condition was described in terms of the school-week observations, and the outcome events were expressed as proportions, by clearly defined denominators. Due to the nesting of learners in 24 schools, the conventional individual-level assessments would underestimate the uncertainty, should the within-school correlation be ignored. A baseline-adjusted random-intercept model would be the suitable model for the subsequent analysis, however, Campbell et al., (2012) and Hooper et al. (2018) assert that in this study no cluster-adjusted coefficient, nor significance test, or causal effect would be estimated.

$$Y_{ij,post} = \beta_0 + \beta_1 T_j + \beta_2 Y_{ij,pre} + \gamma X_{ij} + u_j + \varepsilon_{ij}$$

Equation 1. Baseline-adjusted school-level random intercept model.

In this context, Yij, post represents the post-test score for learner i in school j, Tj is the instructional condition, Yij, pre is the baseline score, Xij is the learner-specific or contextual covariate, uj is the random intercept at the school level, and εij is the error at the individual level. Under the appropriate conditions, it is claimed that β1 would measure the adjusted relationship of the instructional condition to the outcome. Since this model was not run, it is claimed that no descriptive differences cited below would be subject to inferential analysis (Hooper et. al, 2018).

Analytical records included the following: 24 school profiles; 360 learner profiles; 1,080 learner-by-occasion rubric assessments; 240 school-week observations; and 360 transmission observations, all of which were supported by a coded inventory of publicly documented food-processing contexts. Data-integrity checks were conducted for the correspondence of identifiers, observed score ranges, numerical alignment of the rubric and scale, completeness of the assessments, and logical relationships among sharing, recall, and feedback. The researcher ensured that the records were collected and verified during the fieldwork. Internal consistency substantiates the coherence of the reported values. It is not the external validation of the assessment instruments or the fieldwork procedures auditing.

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3.8. Interpretive integration, reflexivity and ethical safeguards

Interpretive synthesis addressed the distinction of documented chemical knowledge without a community presence, the meticulous recording of information without the retention of communication, and the documentation of a sharing event with no subsequent recall by the recipients. These distinctions were contextualised with published community-based research and the theory of knowledge circulation. No fieldwork transcripts or verbatim accounts of community members were included in this analysis; therefore, this study does not provide an interview-based, quoted-based illustrative analysis, and does not provide a substantive quote framework for participants. This provides a framework for justification for the basis of the analysis and the subsequent claims made in the discussion.

For this fieldwork, verbal participant consent was given. Where the ethical interpretation of the engagement of community members in educational practices stipulates that community members should not contractually bind or allow the engagement of their knowledge systems in a manner to be determined beyond what has been agreed, this study differentiates learner assessment from the cultural authority of the indigenous community to control, manage, and regulate the use and dissemination of indigenous knowledge. There is no local restriction to the use of published knowledge.

4. RESULTS

4.1. Study coverage and internal consistency

The analytical sample comprised 24 schools and 360 learners, 180 of whom participated in each instructional condition. There were 190 male and 170 female learner records. Anambra, Abia, Enugu and Ebonyi each contributed 75 and Imo, 60. Each of the urban, peri-urban, and rural schools contributed 120 learners. Scores for all four educational scales were complete for the baseline, post-test and delayed follow up. Of the 1,080 rubric assessments, 360 knowledge-sharing observations, and 240 school-week observations, and 16 predefined checks, a satisfactory range of identifier integrity, rubric concordance, scoring range, and data completeness was observed, along with the presence and interrelatedness of the observed events. These checks allow for a descriptive analysis to be undertaken, the reproduction of which is under the framework of measurement validity, inter-school variability, and research control.

4.2. Descriptive attainment profiles by assessment occasion

Means and standard deviations for the four outcome measures across the three assessment occasions are presented in Table 5. There were small differences at baseline between IFK–ICEP and conventional instruction for literacy, inquiry, documentation and communication of 0.11, −0.01, −0.06 and 0.01 respectively. Post-test means differed by 4.70, 2.95, 4.27 and 3.66. At the delayed follow-up, the means differed by 5.61, 3.71, 5.26 and 4.66 respectively. There is a similar descriptive pattern across outcomes, but the group-level comparisons do not differentiate between the attributes of the programmes, school characteristics, the assessments or other potential confounding factors.

Table 5. Descriptive scores by instructional condition and assessment occasion

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Outcome	Condition	Baseline M (SD)	Post M (SD)	Delayed M (SD)	Gain
Literacy /40	Comparison	16.59 (4.87)	22.10 (5.24)	19.64 (5.56)	+5.51
Literacy /40	IFK-ICEP	16.70 (4.70)	26.80 (5.14)	25.24 (5.46)	+10.10
Inquiry /32	Comparison	11.39 (3.43)	17.32 (3.92)	15.00 (4.29)	+5.93
Inquiry /32	IFK-ICEP	11.38 (3.25)	20.27 (3.82)	18.71 (4.08)	+8.89
Documentation /24	Comparison	8.19 (2.44)	11.84 (3.37)	9.43 (3.43)	+3.65
Documentation /24	IFK-ICEP	8.13 (2.48)	16.11 (3.27)	14.68 (3.56)	+7.98
Communication /20	Comparison	6.22 (2.21)	9.59 (2.82)	6.95 (3.12)	+3.37
Communication /20	IFK-ICEP	6.23 (2.18)	13.26 (3.07)	11.61 (3.39)	+7.02

Source: Fieldwork assessment records. Values are means with sample standard deviations in parentheses; gain = post-test minus baseline; n = 180 per condition.

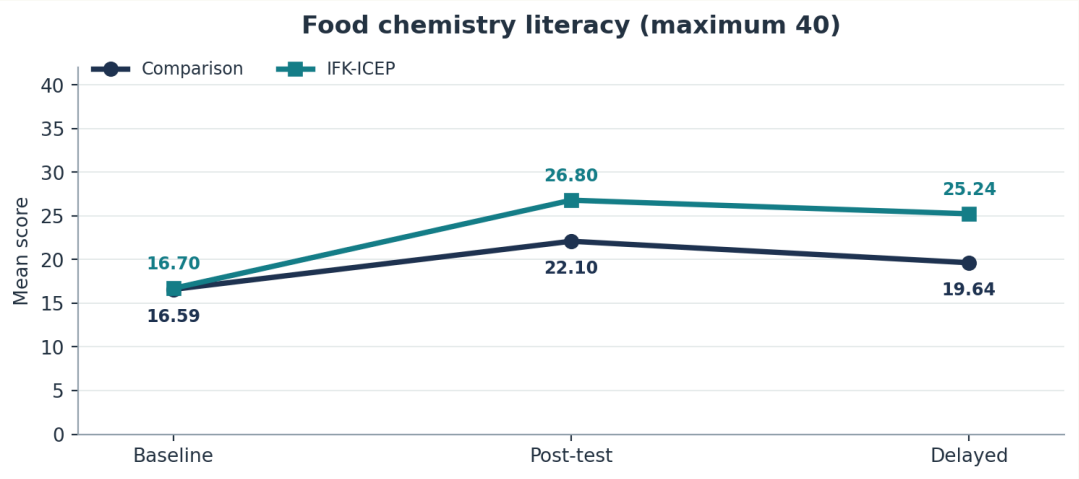


Figure 2. Food chemistry literacy at baseline, post-test and delayed assessment

Source: Fieldwork assessment records; group means (maximum possible score = 40).

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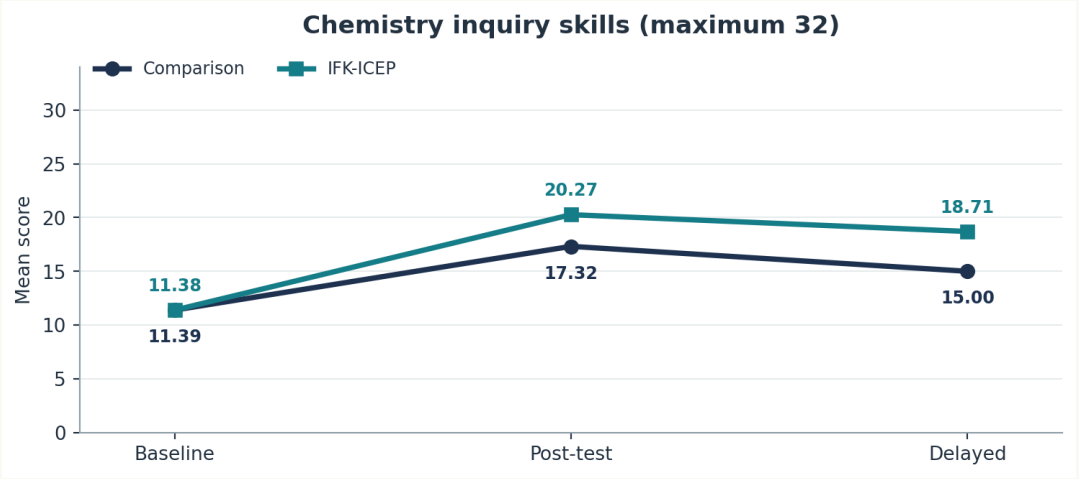


Figure 3. Chemistry inquiry skills at baseline, post-test and delayed assessment

Source: Fieldwork assessment records; group means (maximum possible score = 32).

For all four constructs, baseline means were relatively similar, immediate post-test means improved in both groups and delayed means were lower than their corresponding post-test means. However, the IFK-ICEP group had higher delayed scores in all constructs. The pattern of changes for food chemistry literacy is shown in Figure 2, inquiry skills in Figure 3, documentation competence in Figure 4 and communication competence in Figure 5. The observed changes in assessments are what we describe here. Given score variability, school level clustering, a lack of adjusting modelling and other factors, we cannot attribute a statistically significant effect to the programme.

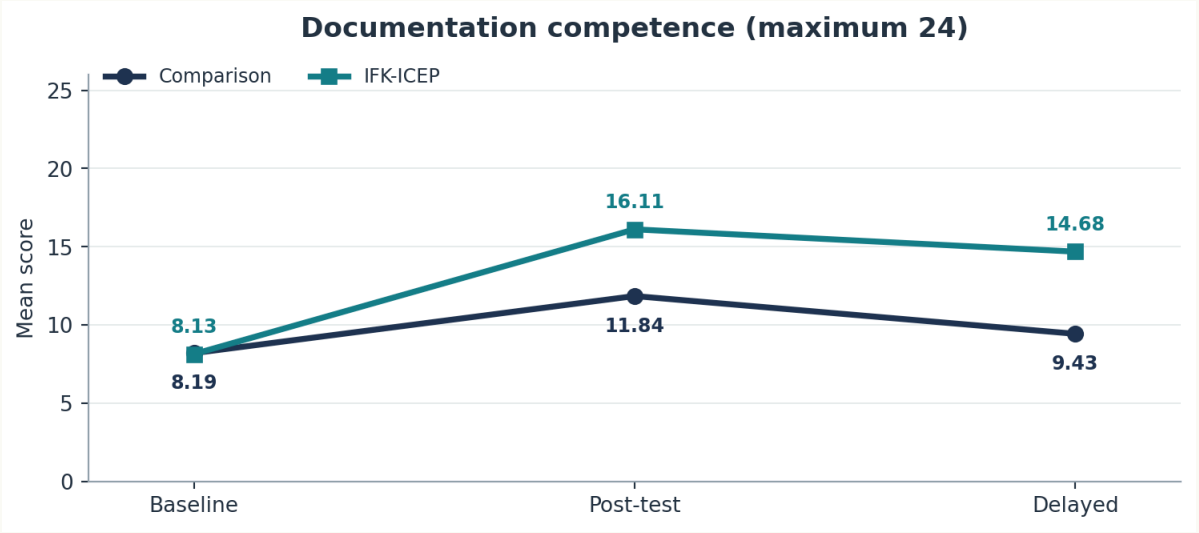


Figure 4. Documentation competence at baseline, post-test and delayed assessment

Source: Fieldwork assessment and rubric records; group means (maximum possible score = 24).

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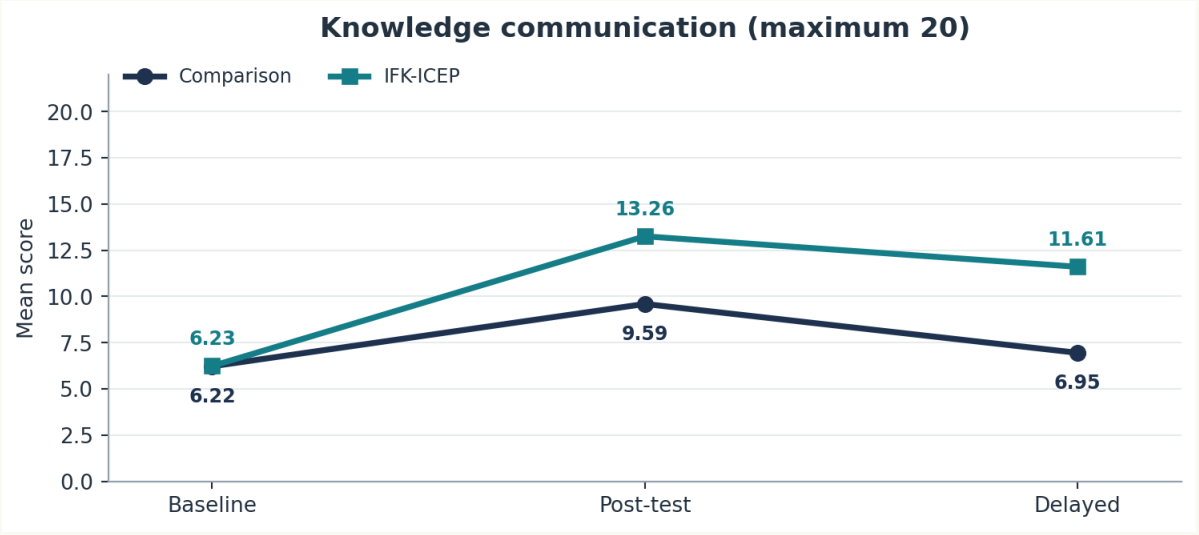


Figure 5. Knowledge communication competence at baseline, post-test and delayed assessment

Source: Fieldwork assessment records; group means (maximum possible score = 20).

4.3. Indicators of knowledge-sharing and recipient recall

Knowledge-sharing events were recorded for 66 learners in the conventional instructional condition, representing 36.7% of the sample, and 129 (71.7%) learners in IFK-ICEP. Positive delayed recipient recall was recorded for 22 (12.2%) and 82 (45.6%) learners in the two conditions, respectively. When only learners with recorded knowledge-sharing events are considered, the respective recall proportions were 33.3% (22 out of 66) and 63.6% (82 out of 129). The mean recipient feedback score among knowledge-sharing event participants was 2.33 for the conventional condition and 3.67 for the IFK-ICEP condition, with no feedback provided for cases without an event. These results affirm that the range and retention of knowledge are separate dimensions of the knowledge transmission process. These results do not support the inference of cultural continuity beyond the documented follow-up period.

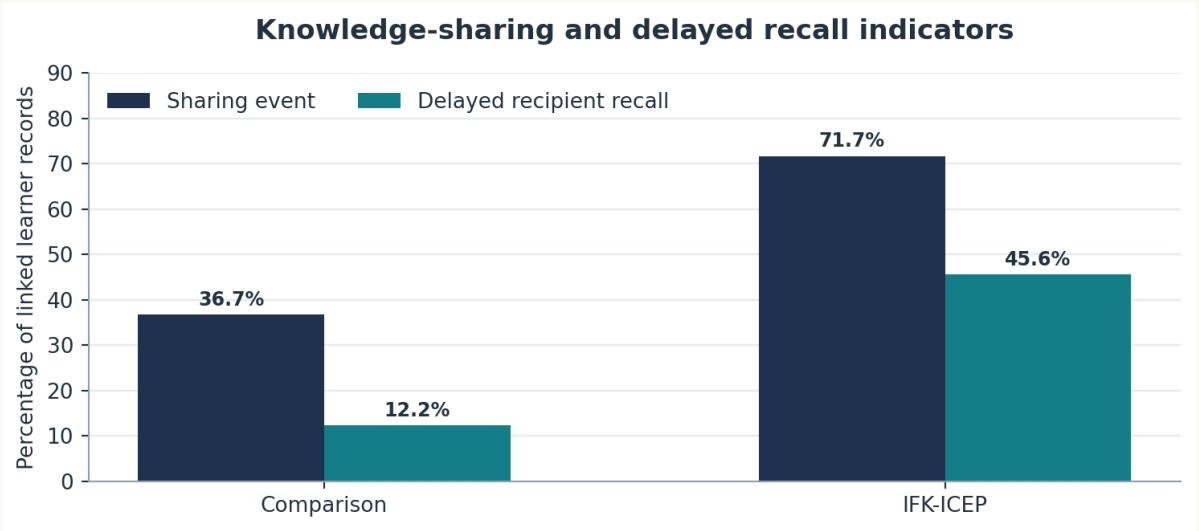


Figure 6. Knowledge-sharing events and delayed recipient recall by instructional condition

Source: Fieldwork transmission records; percentages are based on 180 learners per condition.

Table 6. Between-condition score contrasts per assessment occasion

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Outcome	Comparison gain	IFK-ICEP gain	Gain difference	Delayed mean diff.
Literacy /40	+5.51	+10.10	+4.59	+5.61
Inquiry /32	+5.93	+8.89	+2.96	+3.71
Documentation /24	+3.65	+7.98	+4.33	+5.26
Communication /20	+3.37	+7.02	+3.65	+4.66

Source: Fieldwork assessment records. Changes are descriptive and not adjusted for school-level clusters.

4.4. Instructional Exposure, Heritage Context, and Data Checks

Each of the described instructional conditions provided 120 school week observations equivalent to 9,000 scheduled minutes. With regard to conventional instruction, 8,572 minutes of instructional time was delivered, accounting for 95.24 percent of the scheduled time. The IFK-ICEP condition, on the other hand, had 8,554 minutes of delivered instruction, accounting for 95.04 percent of the scheduled time. The total time delivered for practical instruction was also similar with 3,535 and 3,506 minutes, respectively. Heritage context instruction had 280 minutes in the conventional instruction and 1,809 minutes in IFK-ICEP. The involvement of Knowledge Holders was captured in 6 conventional instruction and 68 IFK-ICEP school week observations. Safety exemptions were captured in 2 and 5 school week observations, respectively. Average recorded fidelity was 89.06 percent and 91.88 percent, respectively. As indicated in Table 7 and Figure 7, the main distinguishing feature of the instructional exposure was the culturally situated content, rather than the overall teaching time.

With regard to instructional examples, fufu, garri, ogi, fermented legume condiments, ugba, and food drying practices, taking into account community permission and the scientific limitations of classroom demonstrations, were included. Components of the level inquiry and documentation scores were reconciled with their total scores. Positive delayed recall was never documented in the absence of a sharing event, and cases without a sharing event recorded no positive feedback. These checks increase confidence in the reported measures, but do not replace inter-rater reliability, confirmed learning instruments, and the acceptable knowledge circulation framework at the community level.

Table 7. School-week Instructional Exposure by Instructional Condition

Instructional indicator	Comparison	IFK-ICEP
School-week entries	120	120
Planned minutes	9,000	9,000
Delivered minutes	8,572 (95.24%)	8,554 (95.04%)
Practical-work minutes	3,535	3,506
Heritage-context minutes	280	1,809

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Instructional indicator	Comparison	IFK-ICEP
Entries with knowledge-holder indicator	6	68
Entries with safety-exception flag	2	5
Mean recorded fidelity	89.06%	91.88%

Source: Fieldwork instructional records. Fidelity values represent the arithmetic mean of school week percentages.

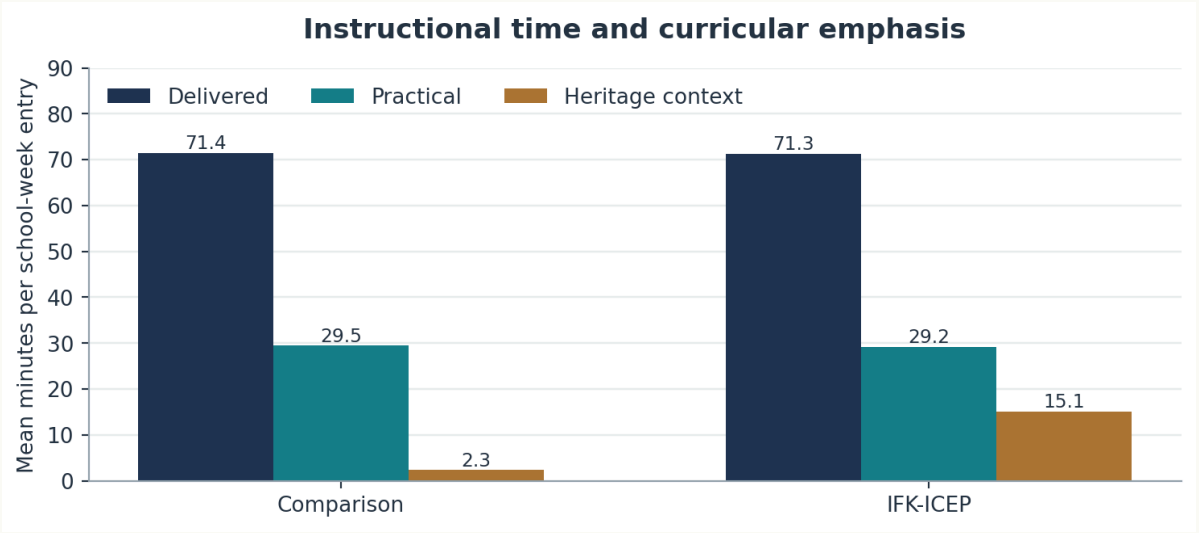


Figure 7. Mean Instructional Minutes per School Week Observation

Source: Fieldwork instructional records; means calculated across 120 school week observations per condition.

4.5. Delayed Learning Retention across Outcome Domains

Table 8 measures retention by reporting the percentage of baseline to posttest mean gain that remained at the delayed measurement. This measure differentiates between the immediate change and the persistence of the change and does not grant value to posttest gain as the defining closure of the teaching and learning process. Between the two conditions, documentation and communication showed the most pronounced differences. In traditional teaching, at the follow-up measurement, 33.8% of the mean gain in documentation and 21.6% in communication, respectively, remained; in IFK-ICEP, the respective proportions were 82.1% and 76.5%. As ratios that are derived from mean values, the proportions expressed the gain, and therefore, the measures should not be interpreted as estimates of retention for the sake of causation.

Table 8. Proportion of baseline-to-post gain retained at delayed assessment

Outcome	Comparison retention	IFK-ICEP retention	Difference (pp)
Literacy /40	55.3%	84.6%	+29.3
Inquiry /32	60.9%	82.4%	+21.5
Documentation /24	33.8%	82.1%	+48.3

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Outcome	Comparison retention	IFK-ICEP retention	Difference (pp)
Communication /20	21.6%	76.5%	+54.9

Source: Fieldwork assessment records. Retention = 100 × (delayed mean − baseline mean)/(post-test mean − baseline mean); pp = percentage points.

Crossing both methods of instruction, 195 learners had a documented sharing event. Of these, 104 demonstrated a positive delayed-recipient-recall. This means that 91 sharing events did not demonstrate a positive delayed-recall. This gap is of substantial importance. While a communication event may have occurred, the ability of the presenter to provide an explanation, as well as the recipient's ability to retain the information, are related, but not equivalent outcomes. The distinction also illustrates that short-term recall is a much narrower measure than the ongoing participation of a member in a community of practice.

5. DISCUSSION

5.1. Distinct domains of learning and heritage continuity

The study disaggregated four educational constructs from two behavioural indicators of knowledge expression. While descriptive statistics for IFK-ICEP showed more merit for food chemistry literacy in terms of inquiry, documentation and communication, absence of attainment and/or event frequency does not necessarily validate safeguarding of living heritage. The study provides evidence for culturally responsive-Science education (and teaching) beyond test score attainment. The authorised (i.e. sanctioned) and reciprocal nature of the documented knowledge exchange is a new frame for evaluation. While the Case Studies in the field of (Critical) Science education and the UNESCO framework establish the basis for cultural (scientific) knowledge and education as a safeguarding imperative, evidence from the field of Chemistry Education in Nigeria (Oladejo et al., 2022) advocates for a renewed interest in evaluating education beyond test score attainment.

There are limits to what is disclosed. It is also within the discretion of the authority figure that restrictions need not always be removed. A positive total for therubric does not mean that the researcher released all restricted techniques, and/or a high frequency of Communication Events do not warrant that the knowledge has been shared. AIFKT-CEM argues that a change in definition of educational goal attainment is warranted, where nondisclosure, if justified, should be considered as scholarly competence.

5.2. Assessment patterns, clustering and rival explanations

Suggestive descriptive patterns can be found when mean scores in a post-test are diverging, but means in a pre-test were similar. These patterns may not account for all of the factors related to the outcome. For example, in this case, there were 24 school units with effective instructional units. There were 360 units of independent intervention. Hypothesis testing should reflect the limits of clustering, assignment at the school level, and intracluster correlation. This should be done with prespecified modelling and sensitivity analysis. The results should reflect measured differences between conditions, not necessarily indicating the measured differences represent evidence of the causal relationship.

Another way of looking at the data may show additional results. IFK-ICEP showed a post-test mean gain of literacy of 84.6%, inquiry of 82.4%, documentation of 82.1%, and communication of 76.5%. For traditional instruction, the post-test mean gains were literacy of 55.3%, inquiry of 60.9%, documentation of 33.8%, and communication of 21.6%. The post-test mean gain for communication and documentation

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may be attributed to the integration of the practices and skills of IFK-ICEP. Other possible explanations may include the type of instruction implemented, the alignment of the teachers with the assessment, and the professional development provided to the teachers.

5.3. Food safety and scientific pluralism

An intervention that integrates chemistry and indigenous knowledge should avoid two symmetrical errors. It should not consider all traditional methods as safe and therefore relying on prior generational knowledge to assess food safety. Assuming something is safe just because it is old and has been practiced for a long time can be a dangerous fallacy, and food safety cannot always be determined by appearance or pH tests. Also, such an intervention should not assess the cultural importance of traditional methods by performing a simple school science project. The cultural importance of a traditional practice should be assessed by the people of that culture. There may be several probable and unstudied chemical and microbial changes in fermented foods. However, it may not always be ethical or prudent to consume the food before further testing and research (Iwuoha and Eke, 1996; Dike et al., 2022).

In line with the above, the concept of science and its boundaries should also be taught to students. It should be made clear that science may not always be able to explain or assess food safety, and if it does, what other evidence should be sought. Rigor should be fostered such that the main ideas lie in potential or unstudied areas of knowledge, and establish the limits of science. This is congruent with the outcomes of several recent research in the field of chemistry education (Mahaffy et al., 2019; York and Orgill, 2019; Zidny, Sjöström and Eilks, 2020).

5.4. Intergenerational transmission as an empirical challenge

Intergenerational transmission is a practice or an interaction. Expecting a more senior member of the community to teach a junior member is not as strong a case as the senior member conducting the teaching session. Conducting the session is not as strong an example as the junior member of the community having understood the knowledge. Understanding the knowledge is not as strong a case as the community using the knowledge. Having a community use and rely on the knowledge is a stronger case than some of the other evidence described above. These practices should not be collapsed into a singular case of ‘heritage preservation’. There are instances where a community is perfectly justified in not disclosing trade secrets to outsiders, and that should not be interpreted as an inability of a community to protect its cultural heritage. (UNESCO, n.d.-a; UNESCO, n.d.-b).

A justified delay in the case might consist of public scrutiny of a step in the process, or evidence from the community that an instructional resource is sound. Repetitive case studies should assess participation of community members in teaching practices, and whether members of the community think the relationship is reciprocal. Such case studies should be of a sufficient duration to assess members’ participation in the practices. Otherwise, such case studies might address the immediate ability of the community to teach members of the community. These studies, however, should not be of practices related to the safeguarding of community heritage.

5.5. Methodological limitations and thresholds of evidence

There are a number of conditioning factors that complicate the interpretation of the findings reported. The study analysed data from 360 learners from 24 schools, and no school cluster-adjusted effect sizes were reported. The presence of complete outcome data does not infer the presence of psychometric validity, and the same applies to the balance of unmeasured and school-related factors. Event codes and recall to name do not provide evidence to support the ways in which knowledge is formed and transformed within the

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community. Evidence of fieldwork and participant consent do not corroborate the conclusions drawn in the analysis.

Further, research involving young learners and Living Human Treasures necessitates an evaluation of the processes relating to authorisation and consent. In the absence of a formal statistical analysis, school authorisation to conduct the research does not imply that the school was extension authorise the researchers to disseminate restricted materials. Requests for children's consent to participate in research, parental and school authorisation do not impact the main research findings, and may be considered in the context of research implementation.

In light of the above, it is recommended that research priority be given to school-level equitable differences, and assess the effects of procedures, processes, timing, language and school organisation in the research. These would be of interest to the research community (Braun and Clarke, 2022; UNESCO n.d.b).

5.6. Curriculum, policy and international significance

Nigerian food processing provides ample context for the preparation of chemistry teachers, but units based on these contexts need to be careful to not to represent methods of one ethnic group as methods practiced across the country. Although a variety of resources such as materials, equipment and language have been reported as main barriers to the successful implementation of projects, I argue that the main barrier has been and continues to be the absence of an interdisciplinary and cross-sectoral alliance. This alliance should preferably comprise the school, food sciences, education departments, local artists and culture practitioners and the community. Schools alone, especially if the projects are undertaken as heritage safeguarding initiatives, have little to no impact and potentially put communities at more risk. The school should implement measures that ensure benefits and positive impacts to the knowledge holders. Safeguarding projects should not be undertaken at the school's own expenses. Schools are obligated to share responsibility and protect communities. In the case of chemistry education,this responsibility means that prior consultation and approval of communities is required for any research to be undertaken with or to communities. This responsibility also means that academically sound justification should be provided when involving and seeking support of communities for the research to be conducted.

6. CONCLUSION

Chemical concepts are closely intertwined with Indigenous food knowledge (IFK), and chemical explanations are at times required to construct scientifically adequate justification. With respect to the communities involved in this research, these kinds of explanations do not compromise food safety. In the context of this research, 360 students from 24 schools demonstrated deeper and more sustained understanding of food, literature, inquiry, documentation and communication in IFK-Integrated Chemistry Education Practice (ICEP), than in conventional Chemistry Education. It showed that documented communication, and knowledge-sharing events in IFK-ICEP were more frequent and positive recipient recall of taught IFK was more long-lasting. There was no attempt to parse out the effect of IFK-ICEP from other interventions or factors. The differences shown serve to confirm the value of independent measurement and study of the areas mentioned.

AIFKT-CEM presents an integrated framework for community governance, cultural responsible assessment and communication, and chemical investigations. This framework is outlined in the context of assessing and evaluating chemistry education. Test scores are only one indicator of learning, much the same way as living heritage is only perpetuated by documented exchange. Research should aim to assess other educational units and eventually combine them with longitudinal assessment. Sustained and reciprocal learning should also be reflected on by the participants. By integrating local food systems and

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practices in science education, Chemistry education can incorporate other ways of knowing, doing and being science, and link it to cultural practices and living heritage without necessitating a 'two-way' approach to teaching.

Ethical Considerations and Data Stewardship

The verification procedures were conducted on research data and that participants consented to participate in the research. The analysis of research data outlines educational outcomes at a national level, whereas outcomes at a community level are not disclosed.

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