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Research Article

Exploring Indigenous Technologies to Mediate Learning of School Science Concepts: Dyeing and Weaving African Baskets

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ABSTRACT: The paper is based on a study that explored a cultural indigenous technology practice of dyeing and weaving African baskets to mediate learning of chemical and physical changes in chemistry. The study contributes to ongoing debates on inclusive ways of knowing, with a particular focus on the Africanization of science education. It advances theoretical, methodological, and pedagogical understandings of how indigenous technology systems can be effectively and meaningfully embedded within formal science curricula. The study offers new insights into contextualized and culturally responsive science teaching and learning within African contexts. The study employed a qualitative case study involving four grade 8 physical science teachers, a critical friend, and an indigenous knowledge custodian as participants. The intention was to expose physical science teachers to the indigenous technology so they could explore its relevance as a cultural tool to support learning of chemical and physical changes. Data sets were gathered using participatory observations and teachers' journal reflections. Vygotsky's socio-cultural theory, together with Shulman's pedagogical content knowledge framework, was employed as a theoretical and analytical framework, respectively. The teachers found a number of school science concepts embedded in the culturally indigenous technology practices of dyeing and weaving. The indigenous technology was thus found to be appropriate and useful for mediating the learning of chemical and physical changes. This study recommends school-based teachers' continuing professional development workshops, where teachers work with community elders in exploring indigenous knowledge practices. The Indigenous Knowledge Custodian can be invited into the classroom to demonstrate the practices to the learners, or the teachers can take learners into the community to observe these practices and make connections to school science. Science teachers are encouraged to explore various indigenous knowledge technologies and identify the science topics/concepts embedded in the relevant indigenous technologies to contextualise science.

Keywords: physical science, chemical and physical changes, indigenous technology, dyeing and weaving, socio-cultural theory, PCK

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Introduction

Science, technology, engineering, and math education (STEM) is proposed as a key factor to facilitate economic and social development (Chakabwata, 2024; Ottevanger et al., 2007; Barakabitze et al., 2019). As a result, many developing countries, particularly in Africa, have shown a greater interest in mathematics and science by investing in and encouraging learners to take up these subjects (Fomunyam, 2021). They have accorded science and mathematics a powerful status in their aspiration to industrialize their nations. However, teaching science to indigenous learners in Africa remains a greater challenge (Mutsvangwa & Zezekwa, 2021; Ogunniyi, 2004). The demand for learners to achieve good results in science subjects has been too high (Reid, 2008). Pressure from such demand has frustrated many science teachers, who feel they have exhausted their teaching methods for learners to achieve as expected. The literature indicates that access to quality science education is limited because school science in many African classrooms is taught in contexts disconnected from learners' realities, largely due to the effects of globalization (Govender, 2016; Koosimile & Suping, 2015). Since school science is westernized, unfamiliar contexts are an exacerbating factor for poor academic performance for indigenous learners. Henceforth, the call for teaching and learning of science innovations that consider learners' sociocultural background as the starting point (Kudumo & Ngcoza, 2023). Culturally responsive methodologies are important for establishing real-world connections in the learning process (Bugtai et al., 2024), with a focus on instructional design that resonates with students' lives, interests, and experiences (Aldemir et al., 2022; Quresh & Demir, 2019).

According to Asabere-Ameyaw et al. (2012), advancing African science education depends on teachers and schools creating space where Indigenous knowledge is recognized as a legitimate form of knowledge. In response, the Namibian broad curriculum clearly calls teachers to incorporate IK and build their lesson instructions on the learners' prior knowledge and experiences (Namibia Ministry of Education, Arts and Culture [MEAC], 2016). Incorporating IK in science curriculum and instructions will potentially make science relevant and accessible to indigenous learners (Shizha, 2013). Moreover, Kudumo and Ngcoza (2023) assert that the integration of IK into the science curriculum can spark learners' interest in science and make science more meaningful in their lives. What remains challenging is the absence of a framework showing how science teachers can integrate these innovative instructional designs aimed at addressing the question of equity and ensuring that all students have access to high-quality science education. This paper explored the following research question:

- "In what ways does participation in the indigenous technology of dyeing and weaving African baskets enhance Grade 8 physical science teachers' pedagogical content knowledge for integrating Indigenous Knowledge in teaching chemical and physical changes?

Background and Statement of the Problem

Literature reveals that the poor performance of non-Western learners in science in African countries, in particular, has been ascribed in part to the fact that African school science is decontextualized in terms of concepts and content (Kibirige & Van Rooyen, 2006; Mavuru & Ramnarain, 2017). Exacerbating the situation, as argued by Sen (2007), is that Eurocentric scientism has been promoted at the expense of Afrocentric epistemologies in science curricula. This means that learners in African schools learn science, which is based on a Western context. It is against this background that IK scholars are calling for indigenous knowledge (IK) to be recognised as valuable science in the school science curriculum (Hewson & Ogunniyi, 2011; Taylor, 2008). Taylor (2008) highlights the importance of a postcolonial concept of *hybridity* to recognize the core existence of Western modern science and Aboriginal science, and this is aimed at supporting Bhabha's (1994) view of cultural translation. To Ganesan et al. (2024), such recognition will help facilitate border crossing issues in the learning environment to enhance culturally inclusive science education. The hegemonies and cultural reproduction of westernized school science delineate (Carlone & Johnson, 2012; Taylor, 2008), marginalize (De Jager, 2019), and make it harder for indigenous learners to understand and interpret abstract science concepts (Govender, 2016; Kudumo & Ngcoza, 2023). However, incorporating IK and practices in science teaching can provide the much-needed context for learning school science.

Namibia has made notable strides in integrating Indigenous Knowledge (IK) into the teaching and learning of science. The National Curriculum for Basic Education (Namibia, Ministry of Education, Arts and Culture, 2016, p. 5) clearly states that the type of knowledge to be imparted to learners is “knowledge that embraces indigenous knowledge (IK) and national culture as well as international and global culture.” However, despite such curriculum intention, there seems to be a disjuncture between curriculum formulation and implementation. It is against this background that this study aims to clarify how science teachers can bring in *indigenous technologies, such as dyeing and weaving African basketry, to* mediate learning of physical and chemical changes. Similarly, Lee and Butler (2003) observed science teachers employing teaching methods and examples that are inaccessible to learners. The decision to bring in an Indigenous Knowledge Custodian (IKC) in this study is supported by several scholars: Asheela et al. (2021), Klein (2011), Lavallee (2009), and Mandikonza (2019). They accentuate that community members possess knowledge of their cultural practices, and such practices can be used in science teaching. Further, it is amplified by the call in Namibia’s MEAC (2016, p. 52) that, “in the community there may be persons with expertise in, for instance, language and cultural traditions, crafts, sport, health, entrepreneurship, or agriculture, who may be approached to support teaching or co-curricular activities.” Within the context of this study, we partnered with an IKC to learn about and participate in the dyeing and weaving of African baskets.

A key limitation of this study was its small sample: four Grade 8 physical science teachers, one Indigenous Knowledge Custodian, and a critical friend, all drawn from a single region. As a qualitative case study, the findings are context-specific and may not be generalized to all teachers or regions. Additionally, the study relied on participatory observations and teachers’ reflective journals, which may be influenced by the researcher's interpretation and participants’ self-reporting bias. Time constraints also limited prolonged engagement that could have provided deeper insights into teachers’ long-term application of Indigenous Knowledge integration in classroom practice.

The focus on chemical and physical changes stems from the first author’s 12 years of experience observing learners’ persistent difficulties with these concepts from grades 7–12. Although many science teachers consider the topic easy, they are often surprised by learners’ misconceptions and limited understanding. Mastery of chemical and physical changes at the junior secondary level is essential, as it forms the foundation for grasping advanced concepts such as chemical bonding and reactions in the senior secondary phase. A glimpse of the challenges faced by learners in their understanding of these concepts revealed in the national examiners’ are as follows:

- The Junior Secondary Semi-External Examination Moderator’s Report (JSSEE, 2018, p. 52) Question 3: “The entire question was poorly answered. The question was totally misunderstood, as many learners thought it was a chemical change. Most learners incorrectly identified the change as a chemical change and, in turn, gave the properties of chemical changes” (Namibia. Ministry of Basic Education, Arts and Culture, 2018)

- Grade 10, JSC Physical Science, Examiner's Report: It surprised national markers that "many candidates did not know the difference between physical change and chemical change … candidates failed to identify which change can be reversed" (Namibia MoEAC, 2016, p. 243); and
- Grade 12, Physical Science NSSCO, Examiner's Report: "Learners confused the difference between physical and chemical testing of water, which relates to the physical and chemical change/reactions topic" (Namibia MoEAC, 2014).

The Namibian case, as revealed in the examiners' reports above, aligns with findings by scholars such as Hanson et al. (2016) and Nakiboglu (2024), whose studies examined learners' understanding of chemical changes and found that they experienced difficulties distinguishing between chemical and physical changes. In light of this, the first author selected the indigenous practice of dyeing and weaving African baskets, seeing opportunities for exploring the distinction between physical and chemical changes.

Teachers need to be aware of cultural or indigenous practices to select appropriate indigenous technologies that contextualise the science concept to be taught (Mandikonza, 2019; Zinyeka et al., 2016; Zidny et al., 2020); hence, the indigenous technology in the study was chosen by the first author based on his knowledge about the opportunities to observe chemical and physical changes. The indigenous technology of dyeing and weaving African baskets is common in Namibia. The indigenous technology is mostly done by elderly women and young women. Men and youngmen take the helping roles, especially in the collecting of raw materials, such as; weaving grass, dyeing agents, mostly plant extracts. Thus, the IKC was invited to share cultural heritage and skills to the teachers on this indigenous technology.

Theoretical Background

This study is underpinned by Vygotsky's (1978) socio-cultural theory (SCT) and Shulman's (1986) pedagogical content knowledge (PCK) framework. Vygotsky's (1978) SCT maintains that learners construct knowledge through social interactions with more knowledgeable others. In support, McRobbie and Tobin (1997) assert that at the social level, meaning is constructed by individuals only when new information interacts with their existing knowledge. Thus, meaning-making from new information is negotiated and achieved through integration of that new information with existing (prior) knowledge. Rojas-Drummond et al. (2013) also advance in their study that learning and development are realised through interactions between teachers (the more knowledgeable others; in the case of this study, the IKC) and learners (the grade 8 physical science teachers).

Within the SCT, we focused on the following constructs: More Knowledgeable Other (MKO), Mediation, Social Interactions, and Zone of Proximal Development (ZPD). Social Interactions and Zone of Proximal Development (ZPD) were further used to analyse the data collected. The SCT was deemed appropriate and relevant; for instance, the IKC was positioned and viewed as more knowledgeable than others MKO. This is because she possessed valuable indigenous knowledge on dyeing and weaving, which science teachers can tap from. Moreover, during the practical demonstration of dyeing and weaving baskets workshops, the participants (physical science teachers, a critical friend, and I assumed the roles of learners and were engaged within our ZPD. Intentionally, the physical science teachers were exposed to these workshops to trigger, if any, a shift in their ZPD.

Shulman's (1986) Pedagogical Content Knowledge (PCK) framework is the totality of professional knowledge teachers possess to successfully translate subject matter knowledge into teachable units. Importantly, according to Shulman (1986), PCK involves, among other domains, "teachers' cognitive understanding of subject matter content and the relationships between such understanding and the instruction teachers provide for students" (1986, p. 25). In this study, it was anticipated that exposing physical science teachers to workshops on dyeing and weaving African basketry would create learning opportunities that could enhance their PCK for integrating Indigenous Knowledge into the teaching of school science. Though Shulman is the seminal author of the PCK framework, Mavhunga and Rollnick (2013) extended his work and identified five topic-specific pedagogical content knowledge (TSPCK) components: students' prior knowledge (including misconceptions), curricular saliency, what is difficult to teach, representations, including analogies and conceptual teaching strategies, and these have been used as the analytical framework. The teachers' ZPD in this study reflects the extent of their knowledge of Indigenous Knowledge and their ability to integrate it into science lessons to support learning about physical and chemical changes, as well as how this understanding developed after engaging in the indigenous practice and workshop activities. The first author intentionally selected African basketry as a mediating tool to shape Physical Science teachers' views on incorporating Indigenous Knowledge into science teaching.

Literature Review

Many scholars, particularly those with an interest in IK, have publicised concerns with regard to the contexts in which school science is taught. School science is decontextualised (Aikenhead & Jegede, 1999; Mavuru & Ramnarain, 2017). Seemingly, the science taught in African schools is typically Western and devoid of African values and cultures (Mavuru & Ramnarain, 2017; Mukwambo et al., 2014). Resultantly, learning school sciences in an unfamiliar context creates a cognitive dissonance between the learners' home experiences and the new classroom knowledge (Aikenhead, 1996; Le Grange, 2007). Based on empirical evidence from numerous studies, IK scholars have reiterated the call for the integration of indigenous knowledge (IK) to make school science relevant and accessible to indigenous learners (Seehawer, 2018; Shizha, 2013; Seehawer et al., 2022).

Defining what indigenous knowledge is, Kibirige and Van Rooyen (2006) show that IK is a legacy of knowledge and skills unique to a particular indigenous culture, which embraces wisdom that has been developed and delivered over generations. Mkabela (2015) similarly defines IK, saying, IK is exclusive local knowledge surviving within and developed in a specific geographical area, possessed by people in a given cultural framework. The elders from the community are the custodians of the IK, which is exhibited through different aspects of life, such as: cultural norms/customs, cultural beliefs, values, songs, languages, cultural technologies, cultural artifacts, games, food, rituals and ceremonies (Klein, 2011; Lavallee, 2009; Nyika, 2017; Seehawer, et al., 2022). Superficially, prior knowledge has often been confined to what learners gain through formal schooling, such as curriculum exposure or content from previous grades (Dolmans et al., 1996). Far less attention has been given to recognizing Indigenous Knowledge as a meaningful form of prior knowledge. Kibirige and Van Rooyen (2006) argue that learners' everyday understandings constitute local Indigenous Knowledge developed through continuous interaction with their social environments.

Das Gupta (2011) found that indigenous knowledge is well-suited to addressing specific learners' needs in local contexts using locally available resources. For instance, culturally sensitive teaching methods reduce the foreignness of science content and make science concepts accessible to learners (Mukwambo, et al., 2014; Taylor & Cameron, 2016). IK integration is also supported by Baquete et al. (2016), they advocate that integrating indigenous knowledge into school curricula could arouse learners' interest in science, and help them at the same time to value and keep alive the knowledge of their parents and grandparents. Moreover, scholars like Ali and Shishigu (2020) and Mabingo (2020) accentuate that the philosophical idea of integrating culturally based knowledge should not only be about the content that learners learn but should also be relevant to learners' everyday life (Gwekwerere, 2016) and be fitting to the values of the community in which they live. Another essential element of valuing IK in school is that it has the potential to increase parental and community members' involvement in school matters as custodians of the cultural heritage (Klein, 2011; Kudumo & Ngcoza, 2023; Mateus & Ngcoza, 2019).

Although Namibia's curriculum endorses the integration of Indigenous Knowledge in science (MEAC, 2016), limited support is provided to teachers on how to implement it in practice. This aligns with Ogunniyi's (2007a) view that those who effectively employ IK in science are typically educators trained in the field at the university level. In response, this study used the indigenous technology of dyeing and weaving baskets to offer Grade 8 physical science teachers a concrete example of IK application. This resonates well with Nashidengo (2013), who advocates that, to realise the integration of IK in school science, capacity building workshops and training should be conducted. This is to mitigate the fact that teacher training institutions do not adequately prepare pre-service teachers on IK integration.

The only option through which teachers could be assisted to improve their teaching practice is via continuing professional development (Eun, 2008). In this study, teachers' CPD was fostered by engaging the participating Physical Science teachers in ongoing workshop-based discussions. The workshop discussion was aimed at affording the Physical Science teachers an opportunity to reflect retroductively on their teaching approach (Chikamori et al., 2019), in light of the indigenous technology they were exposed to or participated in. Most importantly, the teachers critically interrogated their teaching practice through reflections and collaboratively learnt from one another (Chauraya & Brodie, 2018). During the workshops, the teachers explored how to select indigenous knowledge practices that best fit classroom science. These are also known as culturally responsive teaching strategies (Mhakure & Otulaja, 2017; Naidoo & Vithal, 2014). As alluded to earlier, since elders are custodians of the cultural heritage and wisdom, they have an important role to play in making teaching and learning culturally responsive (Klein, 2011; Mateus & Ngcoza, 2019; Kudumo & Ngcoza, 2023).

Methodology

According to Wohlin and Runeson (2021), research methodology refers to the approaches used to generate and analyze data. It outlines how the researcher plans to conduct the study, including the guiding paradigm, research design, participant sampling, data-generation strategies, procedures for data collection and analysis, and the ethical considerations that inform the overall process.

Research Paradigm

Creswell (2016) explains a research paradigm as a lens through which a researcher differentiates worldviews. This study employed an interpretive paradigm as a lens to ascertain the grade 8 Physical Science teachers' pedagogical insights, attitudes, and experiences towards the nature and reality of integrating indigenous knowledge in school science, such as African basketry, to mediate learning of chemical and physical changes. Cohen et al. (2018) explain that interpretive research studies are aimed at providing a rich description of the phenomenon under study as well as providing the answer to the research question.

Research Design

Bertram and Christiansen (2020) describe a research design as the plan for systematically collecting and analysing data to answer research questions. This study employed a case study design. Cohen et al. (2018) define a case study as an in-depth examination of a phenomenon, centred on practice, intervention, and interpretation, with the aim of improvement. The case comprised four Grade 8 Physical Science teachers who participated in a workshop on the indigenous technology of dyeing and weaving African baskets. The unit of analysis focused on learning opportunities created, teachers' perspectives, and pedagogical insights regarding IK integration. A case study was deemed appropriate while seeking an in-depth understanding of how IK can be integrated.

Participant Sampling

A purposive sampling strategy was used to select participants for this study (Cohen et al., 2018). The intended sample comprised four Grade 8 Physical Science teachers with more than five years of experience teaching concepts related to physical and chemical changes. The teachers were approached and invited to participate voluntarily through formal invitation letters. A sample of four teachers, together with a critical friend, was considered sufficient; even if one or two teachers had withdrawn, the remaining participants would still have provided adequate and meaningful data for the study. The position of the researcher as a participant learner did not in any way influence the data collection and analysis, but the dual role as researcher and participant reflects the value of conducting research *with* participants rather than *on* them (Ngcoza & Southwood, 2015). What this means is that, the researcher engaged directly in the activities alongside the science teachers (who assumed learning roles), the researcher experienced the process firsthand, observing how the indigenous practices embody scientific principles such as physical and chemical changes. The researcher did not write reflections; the participatory role allowed the researcher to learn through doing, fostering authentic collaboration with participants while bridging cultural and scientific knowledge.

Teachers' Profiles

All four of the grade 8 physical science teachers participated in the semi-structured interviews. Instead of using pseudonyms, the teachers preferred to be identified by means of codes. The four participants in the presentation are identified as: T1, T2, T3, and T4, respectively, and CF for the critical friend. **Table 1** shows the teachers' profiles. The four participating teachers are fully qualified, each possessing a Basic Education Teacher Diploma (BETD) and an Advanced Certificate in Education (ACE).

The participants were aged 32 to 40 years. Ethnically, the participants were diverse, representing four different ethnic groupings in the Zambezi region of Namibia: Totela, Subia, Lozi, and Mbalangwe. Totela was the language used by the IKC during her presentation, and there was no need for translation as the language was understood by all four teachers.

Table 1. Teachers' profiles

Biographical information	Category	Number of teachers	Code
Gender	Male	3	T1; T2; T3
	Female	1	T4
Teaching experience	1-10	1	T2
	11-20	3	T1; T3; T4
Qualification	BETD	4	T1; T2; T3; T4
	ACE	4	T1; T2; T3; T4
Age	33-38	4	T1; T2; T3; T4
Ethnicity	*Totela*	1	T2
	Subia	1	T1
	Lozi	1	T3
	Mbalangwe	1	T4

Data Gathering Techniques

Given the nature of the study, in which the researcher assumed dual roles as both learner and researcher, participatory observations were employed and complemented by teachers' reflective journals. The reflection journals contained guided question items to which teachers responded, summarizing their engagement throughout the process. These reflections were purposively selected to corroborate and validate the qualitative data obtained from the participatory observations. The guiding question items in the reflection journals will ensure reliability. The interactions of the participants during the practical demonstration of dyeing and weaving by the IKC were both captured using a video camera and audiovisual techniques, with the consent obtained from the participants. Cohen et al. (2018) note that using audio recorders during interviews provides greater accuracy than relying solely on handwritten notes. Recordings allow the researcher to revisit the conversation during analysis — or at later stages—to verify meaning and ensure accuracy. In this study, the audio- and video-recorded interactions from the intervention workshops were also compared with teachers' written reflections, providing triangulation and strengthening the validity of the findings.

Procedure for Data Collection and Analysis

The first author paid several familiarisation visits to the participants, and thereafter held orientation workshops with them. The orientation workshops were initiated to give the participants an overview of their roles during the planned workshops. The IKC made two presentations: preparation of dyes and another on weaving baskets. During the presentation, the IKC teachers' interactions (discussions) were captured using video and audio recordings with the permission of the participants. At the end of the two workshop presentations, teachers were requested to complete their journal reflections on the workshop intervention. The reflections were initiated to validate the qualitative data from the participatory observations.

The IKC's presentations introduced teachers to examples of Indigenous Knowledge relevant for integration with school science. During analysis, emerging themes were interpreted through Vygotsky's sociocultural constructs of mediation and the zone of proximal development. The IKC was viewed as the more knowledgeable other, while the teachers and researchers were positioned as learners. Teachers reflected on their engagement with the indigenous technology, and the analysis explored whether their ZPD shifted following the intervention. To strengthen credibility and reliability, participatory observations were triangulated with teachers' reflections collected across sessions and reviewed during the final interpretation phase for accuracy.

Ethical Considerations

Research ethics involves conducting studies according to acceptable standards of right conduct (Armond et al., 2021; Bertram & Christiansen, 2020). Ethical approval for this study was granted by Rhodes University's Research Ethics Committee (Reference: 2020-1151-3551) via the Faculty of Education Higher Degrees Committee. Permission to conduct the study in the Zambezi region was obtained from the regional education director. The school principal, teachers, and IKC received formal request letters. Informed consent was obtained, with participants reminded that involvement was voluntary and that they could withdraw at any stage. Consent was sought before audio recording or photographing participants during data generation.

Findings and Discussion

These findings presented are in line with the themes that emerged from the qualitative data gathered through participatory observations and teachers' reflections during the workshop.

Teachers' Conceptual Understanding of Chemical and Physical Changes was Enhanced

The theme emerged from the teachers' discussions during the IKC's presentation. It must be noted in the first place that, the teacher's focus was to observe and identify examples of physical and chemical changes, if any in the Indigenous technology of dyeing and weaving. The following are extracts from the teachers' collegial conversations during the workshop leading to the theme:

> *"We say a physical change can be easily reversed right? While, a chemical change is difficult to reverse? Now, after we have pounded (grinded) the larger lump of these barks is it not difficult to change the powder of Munzinzila barks back to those large lumps we started with"? T3*

In response, T1 said:

> *"it is difficult, but … I think we need first to understand the chemical composition of matter before and after it has undergone a change, we know that physical changes do not affect the chemical composition, while a chemical change does".*

CF elaborated that:

> *"What we are seeing is only a change in state, the powdered Munzinzila bark contains no foreign matter, but that which we started with in the beginning."*

The teachers' conversation reveals an initial conceptual tension and gradual refinement of understanding concerning the distinction between physical and chemical changes when contextualized within Indigenous dyeing and weaving technology. This suggests that even teachers themselves held misconceptions on chemical and physical changes just like their learners (Stein et al., 2008). Initially, Teacher 3 (T3) exhibited a common misconception by equating irreversibility with chemical change, reflecting a procedural rather than a conceptual grasp of material transformations—an error frequently reported in science education (Chabalengula et al., 2012). Through collegial dialogue and reflective engagement, Teacher 1 (T1) redirected the discussion toward the underlying principle of chemical composition, emphasizing that physical changes do not alter the chemical identity of substances, whereas chemical changes do. This resonates with Kariper (2017), who posits that, discussions facilitate deep-seated misunderstandings to be identified, diagnosed, and addressed. The critical friend (CF) reinforced this conceptual clarification by noting that the grinding of *Munzinzila* bark represents a "change in state" rather than a change in composition, as no foreign matter was introduced. **Figure 1** shows the grinding process.

Figure 1. Grinding Munzinzila Barks

This dialogic engagement demonstrates a process of conceptual change (Posner et al., 1982), wherein teachers' prior knowledge and misconceptions were challenged and reconstructed through collaborative reflection. In this instance, the use of familiar, locally grounded examples enabled teachers to negotiate scientific meaning within an authentic context, fostering both cognitive and cultural resonance. Overall, the extract evidences how integrating Indigenous Knowledge (IK) systems into science professional learning environments can expose entrenched misconceptions and facilitate deep conceptual understanding.

Findings from Participatory Observations and Teachers' Reflective Journals

The Indigenous Knowledge Custodian (IKC) made two presentations: one on the preparation of dyes and another on weaving baskets. During the presentation, the IKC teachers' interactions (discussions) were captured. At the end of the two workshop presentations, teachers were requested to complete their journal reflections on the workshop intervention (see Appendices A and B). During participatory observations of the Indigenous Knowledge Custodian's demonstration on the dyeing and weaving of African baskets, teachers recorded several processes in their reflective journals and classified them as either physical or chemical changes. These reflections indicate teachers' evolving understanding of scientific concepts embedded within indigenous technological practices. **Figure 2** and **Figure 3** show palm frond preparation, splitting and drying, and dyeing processes.

Physical Changes

Teachers observed, reflected, and identified the following processes as involving physical changes: splitting palm leaf fronds, grinding Munzizila bark, breaking firewood into smaller pieces, soaking dried palm leaves in water, sun-drying wet palm leaves, weaving or knitting patterns on the baskets, and undoing a pattern when a mistake was detected.

Chemical Changes

Processes classified as chemical changes included striking a matchstick, burning wood, and dyeing cream-white palm leaves into brown, yellow, black, orange, and purple. Teachers noted that these transformations were irreversible and involved new substance formation, consistent with scientific explanations of chemical change.

Figure 2. The preparation of palm leaves used for weaving the baskets

Figure 3. Dyeing Palm leaves using Munzizila barks

Figure 4. IKC weaving the base of a basket weaving and T2 observing

These actions were recognized as reversible processes that did not alter the materials' chemical composition. ***Figure 4*** shows a collection of weaved baskets and an end product.

These reflections demonstrate teachers' increasing ability to connect indigenous technological practices to formal scientific concepts, specifically physical and chemical changes. Engaging with the Indigenous Knowledge Custodian enabled teachers to reinterpret traditional practices through a scientific lens, thereby achieving the study's aim of promoting conceptual understanding through the integration of Indigenous Knowledge in physical science instruction. The exercise not only deepened teachers' scientific reasoning but also validated indigenous practices as valuable contexts for science learning.

Teachers' Understanding of the Link between IK and School Science Enhanced

The participatory engagement with the Indigenous Knowledge Custodian (IKC) in the indigenous technology of dyeing and weaving African baskets provided teachers with a culturally grounded context for exploring science concepts. The chosen practice involved dyeing palm leaves using local plant materials extracts such as *Muhonono leaves* and *Munzinzila* barcks respectively, followed by weaving patterned baskets from the dyed leaves. This activity afforded teachers the opportunity to observe, identify, and interpret processes representing both physical and chemical changes. Through this engagement, teachers began to see how Indigenous Knowledge (IK) can serve as a bridge between local practices and formal school science concepts, as envisioned in the national curriculum. Teachers were indeed capacitated as they were clearly observed, articulating clear distinctions between physical and chemical changes in the indigenous practice. Below are some extracts from the teachers' reflections:

> *"Both chemical and physical changes were observed e.g. soaking and boiling. White (nature as they call it) palm leaves in Muhonono leaves turn black, while grinding Munzinzila barks was physical change" (T1).*

> *"Both chemical and physical changes were observed; grinding Munzinzila barks is physical change, while palm leaves changing to different colours is chemical change"(T3).*

> *"On chemical change the palm leaves changed colour when heated in different plant extracts. And colour could not be reversed. I observed physical changes in weaving, when a mistake is done you re-do (T4).*

These excerpts indicate that teachers not only recognized scientific processes within indigenous technologies but were also able to reinterpret them using formal science terminology. This suggests a shift from fragmented to integrated conceptual understanding—one of the key aims of the study. The IK is evidenced through the cultural practice of dyeing and weaving African baskets, which serves as a mediation medium for chemical and Physical chancges concepts. All observed activities within this process represent authentic community-based knowledge transmitted across generations. Teachers identified and reflected on various aspects of the practice that illustrate school science concepts, such as the physical change observed when dry, brittle palm leaves become flexible after soaking in water. This example demonstrates how IK practices embody scientific principles—in this case, physical changes—thereby providing a culturally grounded context for teaching school science concepts.

Further, revelations shows that the chosen indigenous technology presented by the IKC not only allows the science teachers to elicit both chemical and physical changes embedded in it. However, opportunities for other science topics to be mediated were revealed. In this regard, we included these extracts:

> *"Oh, there are many science concepts as well here, Apart from chemical and physical changes, I see forces in action, pushing the awl to make a hole, pushing and pulling the palm leaf strip through the hole made" T1.*

T2, also indicated

> *"There is also pressure here; she is applying a force on an area. When responding to why the palm leaves fronds are split when drying them. T4 said, "That is surface area effect on rate of reactions. When the split strips are left to dry in the sun the strips provide more surface area, that the water molecules inside the fronds quickly heats up and evaporates, this leaves the strips dry".*

To validate the teachers' collegial conversations observed during the IKC's presentations as well as the teacher's reflections. A brainstorming session on the school science concepts embedded in the indigenous technology was held. The concepts that emerged from the expert community members' presentations are shown in **Figure 5** below. These science concepts emerged from the different processes and procedures in the indigenous technology and were clearly linked to school science topics. **Table 2** shows the summary.

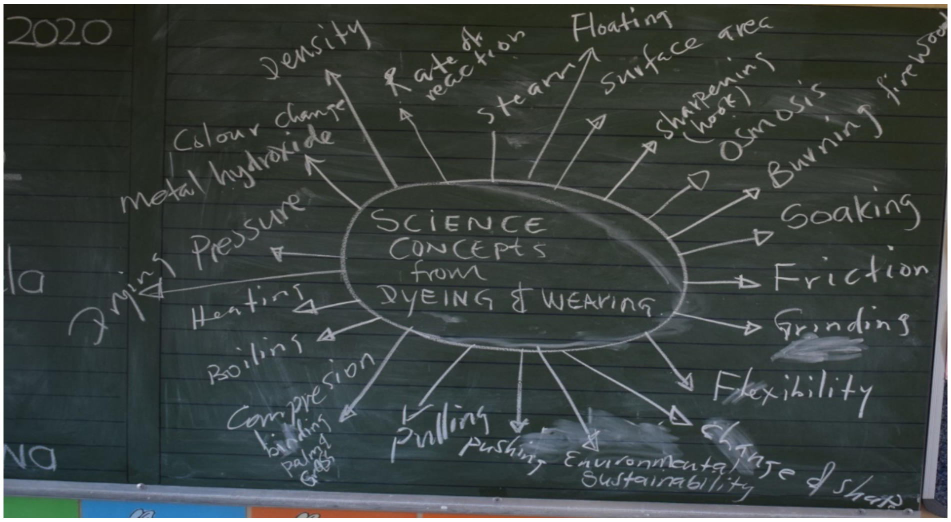

Figure 5. School science concepts that emerged from the IKC's presentations

Table 2. School science concepts that can be taught using drying and weaving as a tool

Practice from the Indigenous Technology	School Science Topic
Splitting palm leaves fronds to allow them dry	Rates of reactions/ forces/ dry and wet mass
Cutting fire wood into smaller pieces	Rates of reactions/ forces
Soaking metal cans in water together with palm leaves	Density, Diffusion
Burning fire wood	Chemical reaction (chemical change)/ energy sources
Dyeing (heating and boiling palm leaves in dyeing agents; plant extracts)	Chemical changes
Using the awl to poke holes	Forces/ Pressure
Weaving baskets (Pulling palm leaves through holes to bind weaving grass)	Push/Pull forces/ pressure
Soaking palm leaves in water (while weaving)	Physical change/ Osmosis/dry and wet mass
Grinding Munzizila barks	Rate of reaction/ surface area/ physical change/

The topics elicited during the brainstorming workshop as it can be seen in Table 2, are covered in various science subjects. For instance, rates of reactions in chemistry, floating and sinking in Physics, osmosis in Biology. The higher observed level of participation and quality teachers' collegial conversation (Chauraya & Brodie, 2018) during the IKC's presentations can only be alluded to the fact that, the chosen indigenous technology served as a best mediatory tool (Vygotsky, 1978). This resonates well with (Ragupathi, 2022) that one of the desired outcomes of any teacher continuing professional development is intervention impact on the participants. In the case of this study the science teachers were enabled to link the Indigenous practises to relevant science (Gwekwerere, 2016). The teacher's understanding of the link between IK and school science, had an impact on the teacher's pedagogy, which is examined in the next theme.

Observed Shifts in Teachers' ZPD and Pedagogy

Theoretically, Vygotsky (1978) defines the Zone of Proximal Development (ZPD), as the gap between what a learner (science teachers) can do independently (how to integrate IK in their lessons) and what they can do with guidance or support (after participation in the IK workshops) from a more knowledgeable other (the IKC). ZPD represents the skills and knowledge that are in the process of developing. The theme emerged from what was empirically *observed.* This is how teachers' capabilities changed through guided participation and social mediation (with the Indigenous Knowledge Custodian, researcher, and peers), as they reflected. The improved understanding was not only observed in the teachers' subject matter knowledge, but also in their pedagogical content knowledge (Shulman, 1986). The extracts from their reflections below are evident to the theme claim:

> *It is much helpful because learners could see for themselves the different changes like grinding the barks remain the same barks, only shape changes. But the dyed palm leaves looks/seem to have something in it that makes it different (T4).*
>
> *Some of the practices used in the presentation would be very useful in my future teaching not only in the topic chemical and physical changes but in other topics too (T1).*
>
> *I will not depend on examples given in the textbook anymore, I will try to give at least 50% of example in the local community (T3).*
>
> *In my selection of teaching aids, I have learned to include some from the local environment. Moreover inviting community members so that they can share the knowledge e.g. traditional way of preserving food (T4).*

The teachers found the Indigenous practice very useful as it can be seen in their keen interest to incorporate it in their future teaching (T1, T3, and T4). T3 and T4 hinted that the Indigenous technology impacted their classroom pedagogy, such that in their selection of teaching and learning aid they will draw and give examples from the local community. This suggests that the teachers would be able to fulfil the curriculum requirements of IK integration in science teaching, Namibia. Ministry of Education, Arts, and Culture, [MEAC], 2016, p. 5).

The study revealed a significant increase in the participating science teachers pedagogical content knowledge (Mavhunga & Rollnick, 2013; Shulman,1986), understanding of the link between the Indigenous technology and its implication for integration. Because of their improved understanding of the relevance of IK and school science, the teachers were enabled to come up with science concepts or topics that emerged and could be mediated by the indigenous technology of dyeing and weaving baskets. This resonates well with Vygotsky's (1978) concept of zone of proximal development as this enabled the teachers to start with what is known to what they want to know. The indigenous science knowledge acted as the base domain knowledge that enable teachers to ensure that learners construct the target domain knowledge in the curriculum. It is because of this reason we say that there were learning opportunities that emerged for the grade 8 Physical Science teachers to use to bridge the gap between curriculum formulation and implementation of IK. The opportunities were the indigenous pedagogical content knowledge (IPCK) which the teachers acquired and the indigenous technical content knowledge (ITCK) for both learners and teachers as there are opportunities of them handling the materials in use (Mukwambo, 2012).

Conclusion and Recommendations

This study advances scholarly understanding of how Indigenous Knowledge systems can mediate teachers' conceptual and pedagogical growth in science education. By engaging teachers in the indigenous technology of dyeing and weaving African baskets, the research illustrates how local cultural practices can serve as authentic contexts for teaching scientific concepts. It extends Vygotsky's Zone of Proximal Development (ZPD) to teacher learning, showing that guided participation with Indigenous Knowledge Custodians fosters autonomous, contextually grounded pedagogy. The study contributes a theoretical and methodological model for integrating Indigenous Knowledge into science curricula to bridge the gap between curriculum design and classroom practice.

The study aimed to identify and establish learning opportunities in the indigenous technology of dyeing and weaving African baskets. This provided grade 8 physical science teachers with ways to bridge the gap between curriculum formulation and implementation of Indigenous Knowledge (IK). The investigation provided valuable insights into the potential integration of Indigenous knowledge and practices into science education. It provides the much-needed context for learning science, as they saw that IPCK and ITCK are useful in mediating science teaching. The results of the study demonstrated a positive correlation between the IKCs' presentation and its perceived value for teaching chemical and physical changes, ultimately enhancing the subject content knowledge of science teachers. In other words, all the teachers found the indigenous technology of dyeing and weaving appropriate and useful to mediate the learning of chemical and physical changes. Further, the study revealed that the teachers' subject content knowledge of chemical and physical changes improved as a result of their collegial conversations as they interacted with the IKC and her mediatory tools. The hands-on nature of the indigenous technology/practices allowed the teachers an opportunity to witness and understand chemical and physical reactions.

As a result of these positive outcomes, the study proposes a series of ongoing school-based teachers' continuing professional development workshops for science teachers. These workshops would serve as a platform for teachers to further explore, understand, and integrate relevant indigenous knowledge and practices into their science lessons. By providing continuous learning opportunities, teachers can continuously expand their knowledge base, fostering a dynamic and evolving approach to science education that embraces the richness of cultural diversity. The ongoing professional development opportunities for teachers should be aimed at bridging the curriculum gap between indigenous knowledge and contemporary scientific knowledge, ensuring a more holistic and culturally sensitive approach to teaching and learning. Furthermore, I recommend a pedagogical shift that acknowledges the interconnectedness of indigenous knowledge practices and scientific concepts.

Finally, this study has opened opportunities for possible further research. We suggest longitudinal research that will examine the sustainability of teachers' conceptual and pedagogical shifts observed in this study; we would like to see a study conducted on the same topic, working with the Physical Science teachers to co-develop exemplar lessons and enact those lessons in their science classrooms. Another study can be carried to explore how Indigenous Knowledge integration influences learners' conceptual understanding and performance in science classrooms, extending the current focus from teachers to student learning outcomes. Lastly, comparative studies between teachers trained through conventional methods and those exposed to Indigenous Knowledge–based interventions would deepen understanding of the pedagogical impact.

Author contributions: All the authors of this study fully endorsed the findings, interpretations, and conclusions as presented in this paper. Each author contributed distinct yet complementary roles throughout the research process. William M. Kakambi was responsible for conceptualizing and designing the study framework, identifying the research problem, and coordinating the overall project. He invited Muzwa M. Mukwambo to join the research team, who actively participated in data collection, analysis, and interpretation. Kenneth M. Ngcoza played a significant role during the conceptualization phase, particularly in refining the research topic, framing the research questions, and providing scholarly and methodological guidance. As the primary supervisor of the author's original Master's thesis, he offered continuous feedback, critical commentary, and editorial input throughout the process. Joyce Sewry, the second supervisor, contributed through detailed reviews, constructive feedback, and editorial assistance in both the initial thesis and this extended study.

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APPENDIX A: REFLECTION ON PREPARATION OF NATURAL DYES

How did you find the presentation on the preparation of natural dyes by the community member? Was it Scientific or unscientific?

……
……

What did you enjoy in the presentation, or anything that relates to science?

……
……

What have you not enjoyed in this lesson, what makes it unscientific?

……
……

From your knowledge of chemical and physical changes, were these (observed) changes chemical or physical?

……
……

What observations (give at least 2 details) make you think that the observed changes are chemical or physical?

……
……

Do you think this presentation could be helpful or not to the learners' understanding of the difference between chemical and physical changes?

……
……

How are you going to use this in your future teaching, to help your learners understand?

……
……

What other science concepts emerged from Mama C1 or C2's presentations today?

……
……

Any other comments?

……
……

APPENDIX B: REFLECTION ON THE WEAVING PROSCESS

How did you find the presentation on the preparation weaving by the community member? Was it Scientific or unscientific?

……
……

What did you enjoy in the presentation, or what makes it scientific/ anything that relates it to science?

………
………

What have you not enjoyed in this lesson, what makes it unscientific?

………
………

From your knowledge of chemical and physical changes, were these (observed) changes chemical or physical?

………
………

What observations (give at least 2 details) make you think, the observed changes are chemical or physical?

………
………

Do you think this presentation could be helpful or not to the learners' understanding of chemical/physical changes difference. How are you going to use this in your future teaching, to help your' learners understanding? Chemical and physical changes differences.

………
………

What could be your reversibility test, to say whether the change can be reversed or not, in this presentation?

………
………

What other science concepts emerged from Mama C1 or C2 presentations today?

………
………

Any comment

………
………