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Integrating Indigenous Knowledge in Life Sciences: Affordances for enhancing Grade 11 learners' understanding of Fermentation

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Abstract
Thirty-two years into democratic liberation, the integration of indigenous knowledge (IK) remains a curriculum priority within South African Life Sciences education. However, less is known about the affordances that IK integration offers for teaching and learning in specific Life Sciences topics. Hence, this study explored how the integration of IK into Grade 11 Life Sciences lessons supported learners' understanding of fermentation. The work was guided by Situated Learning Theory (SLT) and employed a qualitative case study approach. The participants were drawn from 42 Grade 11 Life Sciences learners from a school in Capricorn South District within Dimamo circuit, South Africa. Data were collected through participant classroom observations and documents reviews and analysed using categorical aggregation. The findings revealed that drawing on IK helped learners make sense of fermentation concepts, with caregivers also playing a notable role in shaping this understanding. The study recommends that future research emphasise cooperative learning strategies, embed IK more systematically within the curriculum to create authentic learning contexts, and further examine the influence of caregivers.

Introduction

The recognition of Indigenous Knowledge (IK) within education systems has gained increasing global attention, particularly in relation to culturally responsive teaching and sustainable development. Internationally, organisations such as UNESCO have emphasised the importance of integrating IK into formal education systems to promote inclusive, contextually relevant, and sustainable learning practices (da Silva et al., 2024; UNESCO, 2021). This global shift is evident in countries such as Australia and New Zealand, where IK, particularly that of Aboriginal and Māori communities, has been integrated into national curricula to support culturally grounded and decolonised education (Bishop & Vass, 2020; Burgess & Evans, 2020; Kerr & Averill, 2024). Similarly, across parts of Africa, including Kenya, there have been increasing efforts to integrate IK into formal schooling to enhance culturally relevant pedagogy and address the marginalisation of local knowledge systems (Mutuota, 2023; Owuor, 2007). In the South African context, the recognition of IK can be traced to the 2004 Cabinet approval of the Indigenous Knowledge Systems (IKS) policy, which aimed to formally acknowledge, protect, and promote IK at the national level (Department of Science and Technology, 2004). This policy has informed curriculum transformation processes, including the implementation of the Curriculum and Assessment Policy Statements (CAPS) in 2012. Within Life Sciences, CAPS, particularly Specific Aim 3, which emphasises the need for learners to relate scientific concepts to everyday contexts, including engagement with IK (DBE, 2011). This positions Life Sciences classrooms as important spaces for integrating IK to support meaningful and contextually relevant learning, with teachers serving as key facilitators in this process. Hence, integrating IK helps reduce the isolation of indigenous learners by grounding instruction in authentic, culturally relevant contexts (De Beer & Whitlock, 2009).

IK has been conceptualised in various ways in the literature. Madinkonza (2019) describes IK as confined knowledge derived from interactions among the community, its inhabitants, and its surroundings, while Handayani et al. (2018) define it as society-specific knowledge and skills that enable communities to utilise local resources effectively. Hewson and Ogunniyi (2011) further conceptualise IK as everyday knowledge acquired through lived experiences. In this analysis, we adopt the views of Hewson and Ogunniyi (2011), Keane (2016), and Photo and McKnight (2024). For the purposes of this study, we adopt a stance aligned with Hewson and Ogunniyi (2011), Keane (2016), and Photo and McKnight (2024), and define IK as the knowledge learners gain from their households about the preparation of fermented foods and beverages. This knowledge is orally transmitted across generations and is closely tied to learners' cultural and environmental contexts. Within the Life Sciences curriculum, fermentation forms part of the Cellular Respiration topic and refers to the process by which microorganisms such as yeast and bacteria metabolise carbohydrates into alcohol and carbon dioxide (DBE, 2011; Hanisi, 2016). Linking this scientific concept to learners' everyday experiences provides a meaningful basis for contextualised learning. In addition to IK, this study also draws on the concept of affordances. According to Gibson (1986) and Greeno (1994), affordances are characteristics of a system that enable interactions between the participant and objects, creating possibilities for the participant. They are necessary for activities to produce positive outcomes, as they facilitate engagement between learners and the learning environment (Kennewell, 2001). Components such as laboratory materials and guides can serve as affordances, providing learning opportunities that support desired learning outcomes (Jordan et al., 2011). In this study, affordances are understood as the features of the classroom and instructional context that allow learners to engage effectively with Life Sciences concepts, particularly through the integration of IK (Mayan, 2025)

Despite curriculum intentions to promote contextualised learning, the teaching of abstract Life Sciences concepts, such as fermentation, often remains decontextualised and predominantly relies on Western scientific explanations. Recent scholarship indicates that science education continues to privilege dominant epistemologies while IK remains marginalised or superficially incorporated into classroom practice (Blackie, 2024; Matindike & Ramdhany, 2024). Consequently, learners often struggle to develop a meaningful understanding when scientific concepts are presented in ways that are disengaged from their lived experiences and cultural settings. Furthermore, studies suggest that when classroom content lacks relevance to learners' everyday realities, learner and classroom engagement, as well as conceptual understanding, are weakened (Photo & McKnight, 2024; Gugulethu & Gumbo, 2025). This disconnect may consequently lead to superficial learning, where learners resort to memorising biological processes with little to no understanding of their relevance or practical applications. As such, learners' prior knowledge from their home environments, particularly knowledge related to traditional fermentation practices, is often overlooked in classroom pedagogy, thereby limiting opportunities for meaningful classroom engagement and knowledge construction (Matindike & Ramdhany, 2024; Gugulethu & Gumbo, 2025).

Although previous studies foregrounded the value of integrating IK into science education to advance relevance, learner participation, and cultural inclusivity (Hewson & Ogunniyi, 2011; Matindike & Ramdhany, 2024), there are limited published studies that specifically explore how such integration can fashion meaningful learning opportunities for understanding particular Life Sciences topics, such as fermentation. Existing studies have largely focused on broad curriculum transformation, teacher perceptions, or the general pedagogical benefits of IK integration, with less attention given to topic-specific classroom enactment (Photo & McKnight, 2024; Gugulethu & Gumbo, 2025). Consequently, limited research has explored how Life Sciences learners' everyday knowledge of fermentation practices can be used to promote understanding of fermentation in Life Sciences classrooms. Furthermore, little is known about how such meaningful learning opportunities develop in a given pedagogical context, particularly in a Grade 11 classroom. This underscores the need for content- and context-specific studies that explore how IK can be meaningfully integrated into the teaching of abstract biological concepts, such as fermentation.

In response to this gap, this study aimed to explore the affordances of integrating IK into a Grade 11 Life Sciences classroom, with a specific emphasis on how such integration can enhance learners' understanding of fermentation. By drawing on learners' everyday experiences and cultural practices, the study seeks to demonstrate how connecting IK with scientific knowledge can support more meaningful, contextually grounded learning and deeper conceptual understanding (Hewson & Ogunniyi, 2011; Lave & Wenger, 1991).

Situated learning and educational affordances

Situated learning theory posits that knowledge is not acquired in isolation but is constructed through participation in authentic social and cultural contexts where meaning is co-created through interaction (Lave & Wenger, 1991). In the context of science education, this viewpoint is particularly important because it shifts attention from routine memorisation of abstract concepts to meaningful learning and engagement through real-world practices. Therefore, within this framework, meaningful learning emerges when learners actively engage in activities that reflect the cultural and contextual realities of their everyday lives.

In addition, closely associated with situated learning is the concept of affordances, which refers to the possibilities for action that a learning environment provides to learners (Gibson, 1986; Greeno, 1994). In the context of science education, affordances are understood as pedagogical prospects that emerge when teaching materials, social interactions, and IK are deliberately designed to support meaningful learning (Matindike & Ramdhany, 2024; Photo & McKnight, 2024). In this study, affordances are conceptualised as the learning opportunities that arise when IK is integrated into Life Sciences teaching, particularly through learners' engagement with familiar practices, such as fermentation, in their home environments. These affordances are not inherent in fermentation itself but arise when Life Sciences learners interact with their prior knowledge and the teaching and learning context.

Bridging Western science and indigenous knowledge

The relationship between Western science and IK remains a central concern in contemporary science education. Although science is frequently characterised by abstract, decontextualised, and universalised explanations of natural phenomena, IK is rooted in lived experience, cultural practices, and contextualised interactions with local environments (Blackie, 2024; Mutuota, 2023). Hence, recent studies argue that these knowledge systems are not mutually exclusive but can be complementary when integrated thoughtfully in teaching and learning environments (Chuene, 2024; Kerr & Averill, 2024; Sefoka & Chuene, 2025; Tolbert et al., 2024).

However, several studies also show that science curricula in many contexts continue to privilege Western epistemologies, in which IK serves as supplementary rather than foundational (Chuene, 2024; da Silva et al., 2023; Steenkamp et al., 2018). This disparity limits indigenous learners' ability to connect scientific concepts to their lived experiences. Hence, studies in science education argue that promoting epistemological border-crossing of these knowledge systems can enhance understanding by allowing learners to interpret scientific ideas through culturally familiar frameworks (Chuene, 2024; Photo & McKnight, 2024; Sefoka & Chuene, 2025). In the context of this study, fermentation provides a particularly useful site for this integration, as it is both a scientific process and a practice commonly embedded in Indigenous food preparation traditions.

Pedagogy of Fermentation in Life Sciences

Fermentation is significant in Life Sciences, particularly within the broader concept of cellular respiration, yet it is often one of the most conceptually challenging topics for Life Sciences learners. According to Ramnarain and Mavuru (2020), Life Sciences learners often find it difficult to comprehensively understand fermentation because of its microscopic nature and the abstract representation of the biological processes involved. Consequently, learners often resort to memorising definitions and processes without developing a deep understanding.

In addition, recent studies in science education emphasise the need for more contextualised pedagogies that link fermentation to learners' everyday and lived experiences, particularly food preservation and traditional brewing practices found in many indigenous households (Chuene, 2024; Gugulethu & Gumbo, 2025; Mogashao, 2023; Sefoka & Chuene, 2025). These approaches provide learners with opportunities to relate science to familiar cultural practices, thus making learning more meaningful and relevant. Furthermore, previous studies suggest that integrating IK into Life Sciences classrooms can be strengthened through collaborative approaches, such as cooperative learning, in which learners work together toward shared goals while remaining individually accountable (Jacobs, 2015; Jacobs et al., 2018; Sefoka & Chuene, 2025). Cooperative learning is characterised by positive interdependence, individual accountability, face-to-face interaction, and reflective group processing, all of which can support dialogue and collective meaning-making (De Beer, 2016; Johnson & Johnson, 1986; Lubbe & Petersen, 2022).

In the context of fermentation, group-based learning can create opportunities for learners to share household experiences, compare traditional practices, and negotiate connections between IK and scientific explanations. This is particularly important because fermentation is a socially embedded practice often learned through observation and participation within families and communities. However, despite these possibilities, classroom practice often remains textbook-driven, with limited engagement with learners' prior knowledge and collaborative inquiry. This creates a gap between scientific explanations and lived experiences, making it difficult for learners to fully grasp the relevance of fermentation in real-life contexts. There is, therefore, a growing need for pedagogical approaches that integrate IK and collaborative learning strategies to enhance learners' understanding of fermentation in Life Sciences classrooms.

Home-based practices and caregiver influence on Science learning

The learners do not enter the life Sciences classrooms as empty vessels; rather, they bring with them rich bodies of knowledge acquired from home environments and community practices. The caregivers, including parents/guardians and extended family members, are central to transmitting IK, specifically IK related to food preparation, preservation, and fermentation practices (Munyonyo Asiimwe et al., 2023; Sefoka & Chuene, 2025). These practices establish an essential form of IK that is often neglected in science classrooms.

In addition, recent studies recommend that when IK is acknowledged and integrated into classroom learning, Life Sciences learners are better able to link science concepts to lived experiences, thereby enhancing learner understanding and classroom engagement (Matindike & Ramdhany, 2024; Photo & McKnight, 2024; Chuene, 2024; Sefoka & Chuene, 2025). Though research shows that science classrooms rarely create structured opportunities for learners to draw on caregiver knowledge during teaching and learning. This results in a disconnect between home and school knowledge systems, limiting IK's potential to support meaningful Life Sciences learning.

Culturally familiar language in Science learning

Language plays a central role in shaping learners' meaningful and comprehensive understanding of scientific concepts, specifically in multilingual and culturally diverse classrooms. Science is often taught using highly technical and abstract terminology that may be disconnected from learners' everyday language experiences, thereby creating barriers to comprehension (Sefoka & Chuene, 2025; Setati et al., 2021). Recent research shows that when learners are allowed to engage with scientific concepts using culturally familiar language and everyday expressions, their understanding of abstract ideas improves significantly (Ramnarain, 2023).

In contexts where IK is integrated into science pedagogy, culturally familiar language serves as a bridge between lived experiences and science. This is particularly important in topics such as fermentation, where learners may already have lived experience with processes like food preservation and brewing. Despite these advantages, classroom pedagogy often continues to privilege English scientific terminology, thereby limiting prospects for deeper meaning-making. Integrating culturally familiar language alongside scientific discourse can therefore enhance understanding and support inclusive science learning.

Theoretical Framework

This study is anchored in Situated Learning Theory (SLT), which views learning as a socially mediated process that develops through interactions and relationships within specific cultural, historical, and social contexts (Lave & Wenger, 1991). Instead of viewing learning as the passive transfer of knowledge, this theory proposes that understanding is built through interaction, shared practice, and engagement with real-life experiences. In addition, central to this theory is the concept of legitimate peripheral participation (LPP). This concept describes how learners begin with a bounded participation and increasingly move toward fuller participation as competence develops (Lave & Wenger, 1991; Wenger, 1998). In the context of this study, Life Sciences learners entered the classroom with varying levels of prior exposure to fermentation practices from their homes and communities. These experiences provided a foundation for engaging with scientific information related to fermentation. In addition, this study also draws on the related principle of authentic learning, which emphasises learning through meaningful, real-world tasks and familiar contexts (Brown et al., 1989; Herrington & Oliver, 2000). Authentic learning was reflected in examples such as household fermentation practices, traditional food preparation, and community-based knowledge of fermented products. These familiar contexts helped learners connect classroom concepts to everyday experiences, thereby strengthening engagement and understanding.

Lastly, as previously highlighted, affordances further strengthen this framework by referring to the learning opportunities that emerge when learners interact with supportive environments, tools, and social practices (Gibson, 1986; Greeno, 1994). In this study, affordances included opportunities created through IK, collaborative tasks, authentic examples, and classroom dialogue. These opportunities enabled learners to draw on prior knowledge, compare indigenous and scientific explanations, and develop a deeper understanding of fermentation. As such, SLT was appropriate because it explains how learning can be enhanced through authentic participation, gradual engagement, and pedagogical opportunities that connect home knowledge with school science.

Methodology

Research design and context

This study employed a qualitative, single-case study design to explore the affordances of integrating IK to enhance Grade 11 learners' understanding of fermentation. A qualitative approach was appropriate because it enabled the researchers to examine meanings, experiences, and classroom interactions within a natural setting (Creswell & Poth, 2018). The case study design allowed for an in-depth exploration of a bounded system within its real-life context (Stake, 1995). The study was conducted in one Grade 11 Life Sciences classroom at a secondary school in the Capricorn South District, Dimamo Circuit, Limpopo Province, South Africa.

Participants and sampling

The participants comprised 42 Grade 11 Life Sciences learners selected through purposive sampling. Qualitative research often uses purposive sampling to identify participants who can provide useful, relevant information aligned with the study's goals (Palinkas et al., 2015). The chosen classroom offered direct access to learners studying fermentation and participating in activities integrated with indigenous knowledge. If they were in Grade 11 Life Sciences, went to all three lessons, and agreed to take part, they were included. Thus, the sample contained ample information and was appropriate for the context.

Data collection

Data were gathered across three lessons through participant observation and document review. Participant observation allowed the researcher to document spontaneous interactions, behaviours, and responses in the classroom environment (Merriam & Tisdell, 2016). The first author taught the lessons while observing how engaged learners were, how they talked to each other in groups, how they responded, and how they interacted during class activities. After each lesson, field notes were taken to record what happened in the classroom, what learners said, and what they were thinking. Furthermore, learners finished written assignments at the end of each lesson. Document review is beneficial in qualitative research as written artefacts offer insights into participants' thoughts and experiences (Bowen, 2009). These tasks required learners to elucidate fermentation concepts and relate them to familiar domestic practices.

Role of the researcher

The first author served as both teacher and researcher during the data collection process. Participating as a researcher can give you important insider access to how things work and what they mean in the field (Merriam & Tisdell, 2016). Nevertheless, to mitigate potential bias arising from dual roles, various measures were implemented to reduce undue influence. Learners were told that participating would not affect their grades and that in-class research tasks would not count toward their grades. Only after the teaching sessions were over were the written tasks looked at. Reflexive awareness was sustained throughout the study, and peer debriefing with co-authors facilitated the examination of assumptions and enhanced interpretive neutrality (Lincoln & Guba, 1985).

Data analysis

Thematic analysis, as outlined by Braun and Clarke (2006, 2019), guided the data analysis process. Thematic analysis is a versatile approach for detecting, examining, and presenting patterns in qualitative data. The analysis commenced with familiarisation through the iterative review of field notes and learner-generated responses. After that, open coding was conducted by identifying meaningful segments that illustrated how IK helped learners understand fermentation. Categorical aggregation was used to group similar codes into broader categories, thereby identifying recurring patterns in the dataset (Stake, 1995). After that, the themes were reviewed, refined, and named based on the research question on the benefits of combining IK. Throughout the process, observation notes and written responses were compared to make sure that the interpretations were consistent.

Learners were organised into seven groups of six members each. Each group was assigned a pseudonym and code, namely: group1 (G1), group2 (G2), group3 (G3), group4 (G4), group5 (G5), group6 (G6), and group7 (G7). Individual learners were also assigned pseudonyms and codes: "G" represented a girl in group 1 (e.g., Girl1 from Group1 = G1G1), while "B" represented a boy in group 1 (e.g., Boy2 from Group1 = B2G1). The table below presents the group and individual coding system used in the study.

Table 1: Codes and pseudonyms in the groups

Pseudonym	Code
Boy 1 from Group 1/ Girl 1 from Group 1	B1G1/G1G1
Group 1	G1
Group 2	G2
Group 3	G3
Group 4	G4
Group 5	G5
Group 6	G6
Group 7	G7

Ethical considerations and trustworthiness

Ethical clearance was obtained from the relevant university ethics committee (TREC/88/2022: PG), and permission to conduct the study was granted by the Department of Basic Education. As some learners were minors, assent was obtained from learners and informed consent from parents or guardians. Confidentiality was maintained through the use of pseudonyms and secure data storage. Lastly, trustworthiness was enhanced using the criteria proposed by Lincoln and Guba (1985). Credibility was strengthened through triangulation of observation notes and learner documents, as well as member checking during classroom discussions, in which learners clarified the meanings of their responses. Dependability was supported through clear documentation of procedures across the three lessons. Confirmability was enhanced through peer debriefing among the researchers, while thick description of the study context supported transferability.

The cultural background of the participants

This study was conducted in the Dimamo circuit, located in Limpopo Province, South Africa. The area is mainly inhabited by the Bapedi tribe. The Bapedi people primarily cultivate maize and sorghum. They regarded maize and sorghum as food sources and indigenous staples. For many years, the people of this area have relied on motitielo *(the process of malting)* as their IK for producing fermented foods and beverages.

According to the culture and customs of the people in the Dimamo circuit, traditional beer, Mageu, and homemade bread are served during celebrations. The celebrations include traditional rituals and wedding ceremonies. The elderly women in the community are usually tasked with making the fermented food and beverages. As a result, the elderly women pass on their skills and IK to the young girls they mentor. In some families, traditional beer is not only used for celebrations but also sold to generate income. Young girls exposed to such an environment have the advantage of learning to brew traditional beer. Hence, in this study, the influence of caregivers is seen as an important part of learning through the integration of the community's IK.

Findings and Discussions

This section presents the study's results through a combination of narratives, discussions, and analysis, followed by the emerging findings. In qualitative, classroom-based research such as this one, separating raw data from interpretation is not always feasible because learners' voices, actions, and interactions only make sense when considered within their social and cultural context. Therefore, this section is guided by the aim of the study, which was to explore the affordances of integrating IK into a Grade 11 Life Sciences classroom, with a particular focus on how IK can promote learners' understanding of fermentation

Theme 1: Situated learning and educational affordances in fermentation learning

Learners demonstrated initial and developing understanding of fermentation through both scientific terminology and IK-based explanations. Across the learning activities, learners drew on home and cultural experiences to define and interpret fermentation.

For example, learners linked fermentation to cultural and everyday experiences:

> "G1G1: *Yes, we acquire knowledge about our culture thanks to teaching from family*."
> "G2, G5, G6: *bread-making*"
> "G4 & G1: *breakdown of glucose*"
> "G1, G3, G7, G2, G4: *alcohol production*"

However, conceptual gaps were also evident in the early stages, as learners struggled with key scientific by-products; no group initially mentioned CO_2 as a product of fermentation. Furthermore, learners also questioned the learning process itself, indicating awareness of epistemological boundaries:

> "B2G1: *Is it possible that we may learn fermentation without referring to books?*"

These responses show that learners entered the classroom with partial IK-based understandings of fermentation, which were gradually refined through teaching and learning. The mixture of correct and incomplete responses suggests that learners were operating within an emerging conceptual space where everyday knowledge and scientific explanation intersect. This reflects learning as it occurs through engagement with educational affordances, in which meaning emerges from the interaction between learners' prior knowledge and classroom activities rather than from content alone. Lastly, from a theoretical perspective, this aligns with SLT, in which learning is embedded in authentic activity systems. The classroom environment provided affordances that enabled learners to transition from informal IK understandings toward scientific explanations of fermentation.. This progression in learners' conceptual understanding across the four learning tasks is illustrated in Figure 01 below.

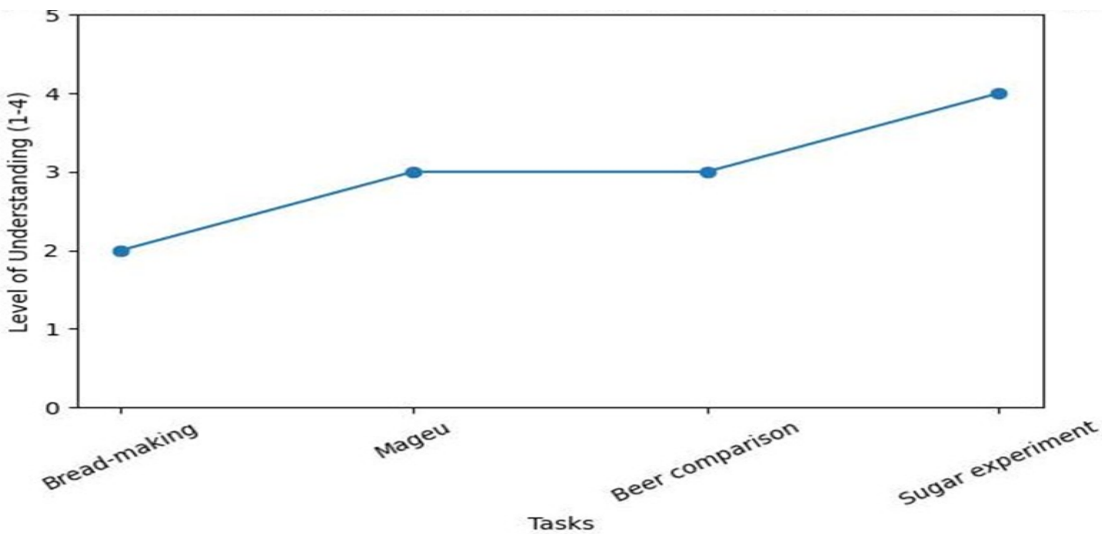

Figure 1: The learners' conceptual understanding across authentic fermentation tasks

Figure 1 shows a clear upward trend in learners' understanding across the four fermentation-related tasks. Conceptual understanding was initially lower during the bread-making task (Level 2), where learners appeared to rely more on everyday prior knowledge than on formal scientific explanation. Understanding improved during the Mageu activity (Level 3), suggesting that engagement with a culturally familiar fermentation example supported learning, and remained stable during the beer comparison task (Level 3), where learners compared traditional and industrial practices. The highest level of understanding was reached during the sugar experiment (Level 4), where learners could directly observe fermentation outcomes through hands-on investigation. This progressive increase suggests that learners developed a stronger conceptual understanding when fermentation was taught through authentic, familiar contexts. From the perspective of SLT, these findings indicate that authentic contexts created educational affordances for learning, as increasingly interactive and observable tasks enabled learners to connect IK with scientific concepts, thereby supporting more meaningful learning in Life Sciences.

Theme 2: Bridging indigenous knowledge and Western science in fermentation

Learners demonstrated the ability to distinguish and connect traditional and scientific explanations of fermentation processes. In comparing traditional and industrial beer-making, learners stated:

"G3G1: *The two procedures are similar; industrial beer is made using machines, and traditional beer at home is made manually.*"

"B2G3: *There is a minor distinction between the two methods.*"

Learners also demonstrated emerging scientific reasoning about fermentation outcomes:

"B1G3: *More sugar → more CO_2 → larger balloon sizes.*"
"B5G1: *Carbon dioxide*"

These results demonstrate that learners could transition between IKS and Western scientific explanations. Instead of seeing them as two separate things, learners began to combine both points of view when thinking about fermentation. This corroborates literature positing that substantive science education transpires when IK and Western science are regarded as complementary rather than antagonistic frameworks (Chuene, 2024; Sefoka & Chuene, 2025). In terms of SLT, learners were engaging with overlapping knowledge systems in a real learning environment and were gradually moving toward fuller participation in scientific discourse (LPP). Figure 02 below illustrates how IK and scientific understanding have become more integrated over time, another way to show this developmental change.

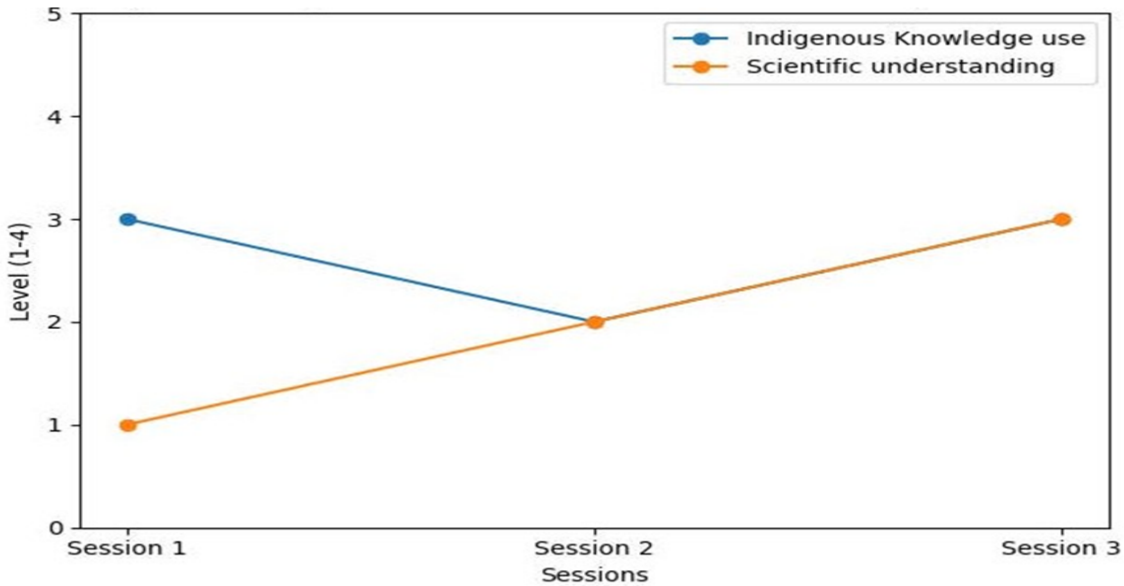

Figure 2: Integration of IK and understanding over time

Figure 2 shows that over the three sessions, IK use and scientific understanding increasingly came together. In the beginning, learners relied more on IK, which didn't explain things very well from a scientific perspective. But by the end, both knowledge systems were used in a balanced way. This progression shows that when IK was clearly integrated into classroom teaching, learners began to use more meaningful scientific reasoning.

In Session 1, IK is much higher than scientific understanding, which means that the learners mostly used explanations of fermentation that they were already familiar with from their culture, rather than many formal scientific ideas. By Session 2, however, both IK use and scientific understanding are at the same level. This means that learners are beginning to bring the two systems of knowledge together rather than keeping them separate. This midpoint reflects an emerging epistemic shift toward integration.

During Session 3 observations, scientific understanding increased to match IK use, and gesturing strengthened engagement with disciplinary scientific explanations while still maintaining IK as part of their reasoning. Notably, the stability of IK alongside the rise in scientific understanding indicates complementarity rather than replacement. Therefore, it can be deduced that the pattern reflects a progressive shift from reliance on prior IK to integrated, dual-framework reasoning consistent with LPP.

Theme 3: Pedagogy of fermentation and collaborative meaning-making
The learners repeatedly worked collaboratively to construct meaning around the processes involved in fermentation, particularly during discussions of yeast, sugar, and gas production. Evidence of shared reasoning included:

"G3G7: *What caused the balloons to expand?*"
"G1G2: *Sugar was not added to starve yeast; CO_2 not released.*"
"G2, G4, G6: *Alcohol production*"
"G2 & G5: *With heat, yeast breaks down sugar…*"

The learners also exhibited peer-based correction and negotiation of meaning across groups. These exchanges exhibit that learning was socially constructed through negotiations and peer explanation. As such, group interaction supported learners in refining their misconceptions and co-constructing scientific understanding of fermentation. Furthermore, this aligns with research highlighting the effectiveness of collaborative learning in science education when integrating IK (Chuene, 2024; Jacobs et al., 2019; Sefoka & Chuene, 2025). Hence, within SLT, these interactions represent participation in a community of practice where learners learn through social engagement and shared problem-solving.

Theme 4: Caregiver influence and home-based indigenous knowledge
The learners explicitly connected their understanding of fermentation to the knowledge they gained from their caregivers/guardians and home environments:

"G1G6: *I saw my grandmother doing it.*"
"G4G7: *I saw my mother doing like that.*"
"G4 & G3: *Use of traditional beer foam*"
"G2, G3, G7: *Mapoto (local term for fermented drink)*"

The learners raised in households with active fermentation practices exhibited stronger explanatory confidence during classroom discussions. These findings show that caregivers serve as key transmitters and custodians of IK, particularly regarding food fermentation practices. Therefore, home environments serve as foundational learning spaces that are central to shaping the learners' scientific understanding, which is important for formal schooling. This supports Munyonyo Asiimwe et al. (2023) and Sefoka and Chuene (2025), who underscore intergenerational knowledge transmission as central to IK. Hence, within SLT, caregivers/guardians signify the initial community of practice, from which the Life Sciences learners enter school-based participation (LPP). As such, Figure 03 provides a visual representation of learners' progression from peripheral to more active participation, consistent with LPP within SLT.

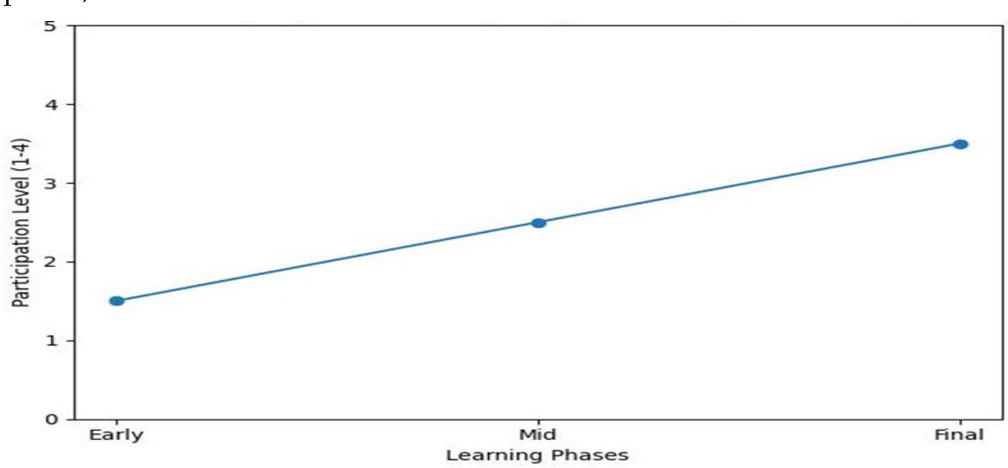

Figure 3: Learner progression through LPP

Figure 3 demonstrates a clear development in Life Sciences learner participation consistent with LPP within SLT. This means that the Life Sciences learners at the outset participated at a peripheral level, characterised by constrained contributions, reliance on observation, and tentative use of scientific language when explaining fermentation concepts. At this stage, participation was mainly descriptive rather than explanatory, exhibiting early entry into the classroom community of practice. Conversely, over time, there is a visible shift toward more active and confident engagement. Furthermore, the learners begin to contribute more substantively during discussions, providing explanations that centre both IK and scientific concepts. This suggests a gradual strengthening of their epistemic positioning within the classroom, as they move from passive observers to more active participants in knowledge construction. This shift reflects greater inclusion in classroom knowledge construction processes, where learners are afforded more opportunities to articulate, test, and refine their understanding through peer and teacher interactions.

Theme 5: Culturally familiar language as a learning affordance

Learners demonstrated improved engagement and understanding when culturally familiar terminology was used in teaching:

> "G3 & G1: *Mapoto*"
> "G4 & G5: *Identified similarities between traditional and industrial beer*"
> "G2G3: *What do other groups understand about alcoholic fermentation?*"

Learners showed better participation when explanations were framed in culturally familiar terms rather than purely scientific language. The use of culturally familiar language functioned as a cognitive bridge between learners' lived experiences and abstract scientific concepts. This reduced conceptual barriers and supported more inclusive participation. This supports Ramnarain (2023) and Sefoka and Chuene (2025), who argue that language is central to meaning-making in science. Therefore, within SLT, language is part of the authentic practice that enables legitimate participation in disciplinary knowledge.

Conclusion

The findings of this study signify that integrating IK into the teaching of fermentation in Grade 11 Life Sciences created meaningful opportunities for the Life Sciences learners to deepen their conceptual understanding. The use of recognisable examples such as traditional beer, Mageu, and bread-making enabled learners to relate Life Sciences concepts to practices encountered in their everyday lives. Furthermore, learning was reinforced through the use of accustomed language and knowledge shared within families and communities, which seemed to make the concept of fermentation more accessible. These findings suggest that acknowledging learners' cultural resources and IK can reinforce both understanding and relevance in Life Sciences learning.

Furthermore, beyond the integration of IK, the cooperative learning approach emerged as an important teaching mechanism through which learners negotiated meaning, exchanged ideas, and collectively refined their understanding. The group interactions provided a conducive learning environment in which learners with prior knowledge of fermentation could support peers, thereby contributing to collaborative knowledge construction. This resonates with SLT, which sees knowledge development as socially mediated and shaped by the environment. Furthermore, the participating learners demonstrated the capacity to move between IK and Western science, identifying areas of complementarity rather than treating the knowledge systems as opposites.

Therefore, the study contributes to the current discourse on the value of inclusive and contextually receptive Life Sciences education. Furthermore, it emphasises the implications of intentional classroom pedagogy that integrates IK. In this regard, teachers may be supported to integrate IK more deliberately, while curriculum developers could consider embedding indigenous examples within formal curriculum structures to promote equity, relevance, and learner engagement. Although this was a single-case study, the findings suggest that IK integration has broader potential to support learning in Life Sciences. This study recommends;

i. Emphasise cooperative learning: The study found that the cooperative learning strategy used in teaching fermentation encouraged learners to develop their own interpretations of the facts and conclusions. As a result, teachers should stress cooperative learning in their teaching techniques. Integrating IK into the curriculum.
ii. Create an authentic context for learning: According to the study, learners learn better when they are involved in activities in a realistic setting. As a result, teachers should establish an authentic learning context by enabling learners to use familiar terms and immersing them in familiar settings.
iii. Encourage positive caregiver influence: The study discovered that learners' learning styles are impacted by their culture and the people around them. As a result, teachers should support positive caregiver impact by including carers in the learning process and enabling learners to share skills gained from caregivers with other learners.

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