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A Formative Study Towards the Inclusion of Indigenous Technologies and Knowledge Practices in Science, Technology, Engineering, Arts, and Mathematics (STEAM) Curriculum Settings

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Abstract

This work on STEAM and education for sustainable development was undertaken across a series of collaborative case studies as formative research on the inclusion of Indigenous technologies and knowledge practices in teacher education. We noted that, despite the current academic imperative to decolonise southern African education, one seldom finds the inclusion of Indigenous technologies and Indigenous heritage practices in the contemporary classroom. Teachers we worked with were highly interested in their Indigenous knowledge heritage. Yet, they reported that they, and the young teachers they work with, simply do not have the heritage knowledge capital to include Indigenous knowledge systems in their teaching. Other challenges they face are the time it takes to engage community knowledge holders, and to find knowledge relating to school subject disciplines. The teachers observed that students prioritise modernity over Indigenous heritage and technologies, often undervaluing the latter as a forgotten past. Three exploratory cases delved into teacher education's response to challenges through co-engaged work, and this paper synthesises the

emerging evidence—aiming to refine pedagogical tools for integrating Indigenous knowledge into STEAM education. A cultural-historical approach was used to frame the study and to derive insights and inferences in co-engaged lesson design research with teachers.

Keywords: Indigenous knowledge systems, Indigenous knowledge, Indigenous heritage, STEAM

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Background

There is a great need to strengthen the South African curriculum by integrating Indigenous knowledge systems (IKS)[1] into science, technology, engineering, arts, and mathematics (STEAM) education. Godson et al. (2024) noted the role of IKS in enriching education and its potential contribution to scientific knowledge through integration into STEM (science, technology, engineering, and mathematics) education, which focuses on emphasising technical skills and problem solving.

STEAM education takes this process one step further by integrating the arts into the framework, emphasising creativity and interdisciplinary thinking and fostering creativity, critical thinking, and innovation through the arts. STEAM encourages active transformative education by nurturing holistic learning experiences where students engage in real-world problems, think creatively, and develop empathy. By incorporating the arts, students can approach challenges from multiple perspectives, leading to more innovative solutions and a deeper understanding of complex issues, making STEAM education ideal for fostering active transformative learning through integrating IKS.

The research comprised three case studies conducted with teachers in 2023 as part of the Fundisa for Change (https://fundisaforchange.co.za/) teacher education programme. The collaborative work took the form of course-mediated lesson planning work with teachers who explored the inclusion of Indigenous technologies (artefacts) and knowledge practices in their subject teaching in the Intermediate and Foundation Phases of the CAPS curriculum.

An Opening Review to Inform the Studies

The inclusion of IKS in curriculum policy emerged and developed within an opposing of African Indigenous and Western knowledge systems. This epistemic dialectic, being repetitively influenced by the continuities of coloniality (Bhurekeni, 2020), is found in the works of Jegede and Aikenhead (1999), Odora-Hoppers (2001), and Nagara (2017), for example, and has developed as a characterising feature of IKS as a decolonising field of study and practice. Survey research has also opened up the field, and IKS has emerged as a developing concern that, despite education policy imperatives, it is not yet widely evident in school curriculum settings in the southern African region (Mkosi, 2005; Ngulube et al., 2015).

[1] IKS is read as Indigenous knowledge practices and technologies that can situate and frame STEAM to reappropriate Indigenous technologies and practices in ways that enhance the relevance of learning in these curriculum subjects.

The developing discourses have, in a variety of ways, called for inclusion, a transcending of boundaries on the epistemic front (Jegede & Aikenhead, 1999) and an expanding of narrow perspectives in curriculum settings so that the plural character of heritage knowledge systems (Nagara, 2017) is reflected in teaching and learning. When viewed through this lens, the modern classroom can be interpreted as a nexus of knowledge systems including the contemporary knowledge found in modern institutions, which is frequently manifested in the formal curriculum as school subject disciplines.

As noted earlier, despite a proliferation of Indigenous knowledge (IK) literature and its integration within a widening field of IKS, we did not find clear cases where IK is included in classroom teaching in ways that heritage might articulate with modern subjects relating to the needs and life experiences of the people today. A noted unique feature of IKS in curriculum and pedagogic innovation is that these are often transmitted orally, through observation and practice, in a dynamic process that meets the needs of a particular community (Cláudio da Silva et al., 2023). This calls for changes in curriculum policy and we thus outline here, an approach to the inclusion of IK.

Towards a Collaborative Research Design

The evidence in the brief literature review pointed to a need for framing theory-informed research on the inclusion of Indigenous technologies and knowledge to enhance the relevance of learning to enrich and transform conventional classroom teaching. A primary purpose of this research was thus to clarify models of process towards the inclusion of Indigenous technologies and knowledge to strengthen the current knowledge-mediated curriculum through more inclusive lesson design research with teachers. In this context, we will present three case studies:

- The inclusion of heritage knowledge in course-supported lesson design work (2021–23 field notes by Snow and O'Donoghue, as reported in Schudel et al., 2021).
- Activating heritage knowledge in an online teacher education programme (2023 evaluation notes by O'Donoghue and van Staden).
- Deliberative work to surface IK in science education (Ndlamlenze & O'Donoghue, 2023).

The research was centred on the abductive development of inferences that might better inform the inclusion of Indigenous technologies and knowledge practices in conventional subject teaching. These collaborative studies were thus located in our teacher education work and centred on the derivation of abductive inferences where abduction involves reinterpretation as researchers begin with a theoretical framework, thereby reinterpreting and attributing new meaning or significance to the phenomenon being studied or constructing theory through its application in new context (Bergene, 2007). The case evidence from the three cases is drawn together in this exploratory review of the successive design research undertaken with teachers. As a Fundisa for Change process of teacher professional development, we explored the inclusion of Indigenous technologies and knowledge practices within Education for Sustainable Development (ESD) as a reflexive process of transformative learning. The imperatives to include IKS and ESD in curriculum strengthening are now being treated as cross-cutting concerns by the South African Department of Basic Education (2023).

Clarifying Co-Engaged Design Research Methodology

Figure 1 reflects the 4-phase lesson design research methodology against the generic model for educational design research after McKenney and Reeves (2012). The focal topic for the small-scale

case studies with teachers was the inclusion of Indigenous technologies and knowledge practices in lesson planning. The study drew on contemporary cultural-historical and language studies approaches that accommodated the inclusion of IK and transformative competences informing education for sustainable development (ESD). The suggested Handprints for Change learning progressions included a 4-phased learning progression developing around start-up story sharing, inquiry, data analysis, and the application of knowledge in change challenges (O'Donoghue et al., 2020).

Figure 1

A Developmental Concept Map of the Task Sequencing Design Process and the Qualitative Assessment of Learning Transactions (Adapted From McKenney & Reeves, 2012)

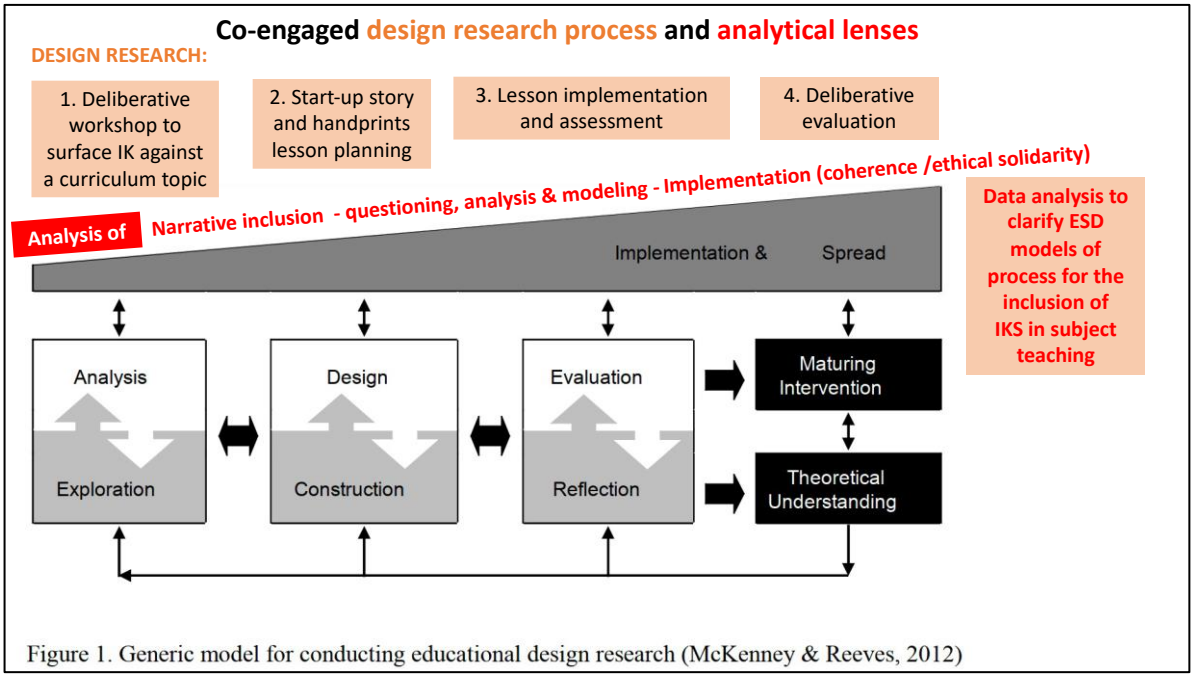


Figure 1. Generic model for conducting educational design research (McKenney & Reeves, 2012)

To frame ESD as a transformative progression of process skills, we worked with an expansive learning cycle after Engeström and Sannino (2020) and the 4-quadrant Vygotskian task sequencing of Edwards (2014), as shown in Figure 2. Here, Sannino and Engeström (2017) provided a formative intervention model of process as an analytical lens for the deliberative mediation of learning-led change.

Figure 2

Planning ESD as Real-World Transformative Learning

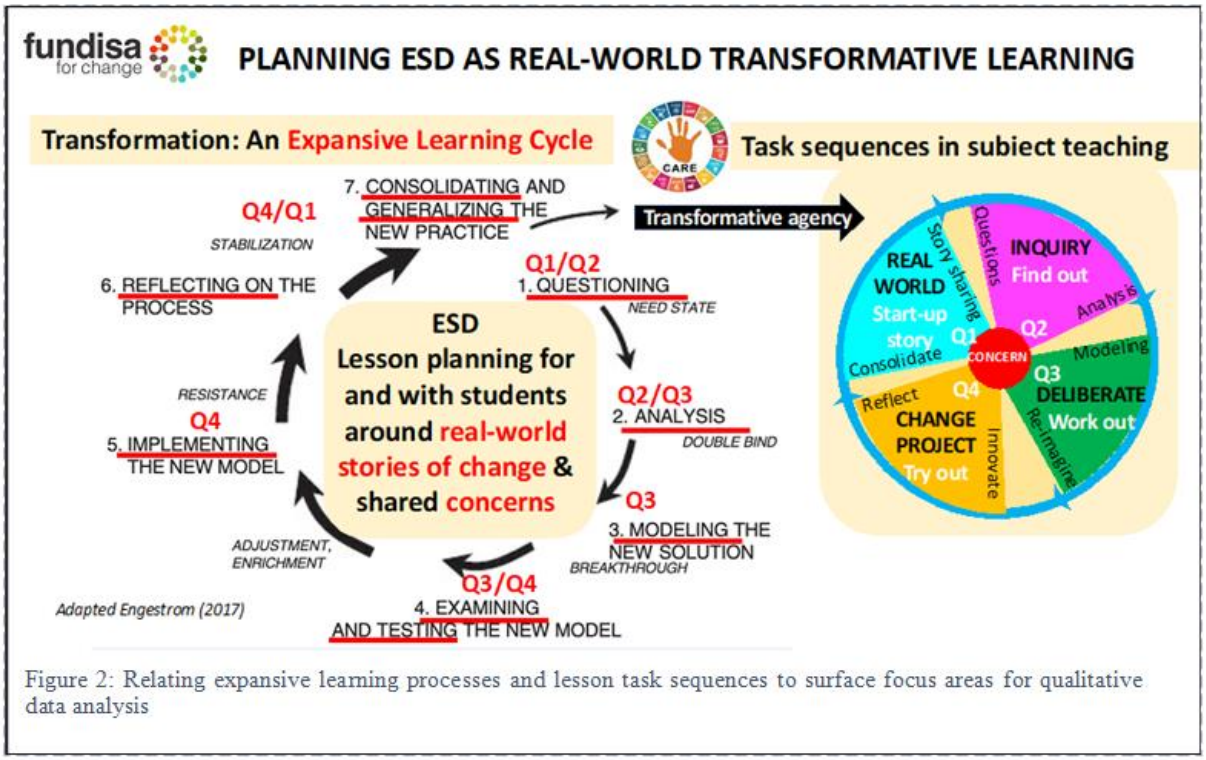


Figure 2: Relating expansive learning processes and lesson task sequences to surface focus areas for qualitative data analysis

The close coupling of social learning theory and lesson task sequences in Figure 2 enabled us to frame a knowledge-mediated action research process for our course-supported work with teachers. Here, our attention was centred on Indigenous technologies and knowledge practices as an intergenerational platform to raise questions to guide inquiry-based learning. Through the task sequences, teachers could mediate, track, and assess learning as an expansive process in relation to the matter of concern.

Working in this way to explore a cyclical process of transformative learning within a pedagogical process of unfolding task sequences, we were able to deliberate and review:

- the lesson design and its mediating pedagogy as an ESD process and
- the inclusion of Indigenous technologies and knowledge practices to activate heritage learning.

Our research concern here was thus both the inclusive mediation of a heritage-activated learning process and the development of the necessary models of process to support this. During the pilot studies, teachers were co-design researchers within a teacher education programme working together to develop lesson plans around IK heritage. Working in this way, we were able to review inclusive learning transactions through the qualitative tracking and analysis of a developing learning programme, namely, the practical coherence of knowledge within an ethical consensus, and abductive inferences evident within a co-engaged design research methodology. Here, evidence of inclusion was verified within the lesson design submissions of participants and in their reports on lesson implementation.

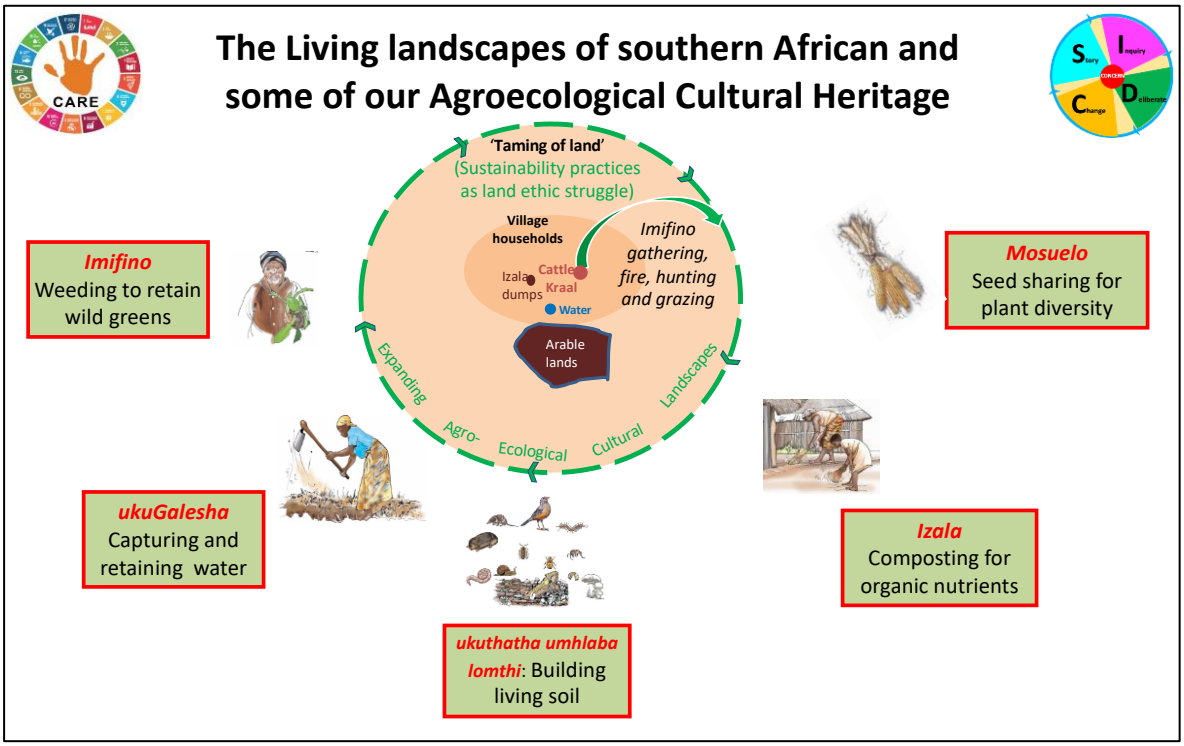
The Course-Mediated and Deliberative Uncovering of Indigenous Heritage Knowledge

The framing theory for the pilot studies reported in this paper was centred on the outcomes of the first stage of a course-mediated design research process, namely, the surfacing of IK and real-world story materials for opening up questions in relation to local matters of concern.

The cases reported here necessitated a decolonising of the prevailing environmental histories of the region. Colonial environmental histories inscribed Indigenous peoples as both the fallen "children of nature" (Walker & Richards, 1975) and destroyers of nature (Pringle, 1982). A revised living-landscape perspective uncovered how Indigenous peoples' agroecological practices have shaped and enabled them to live within the extreme climate in the living landscapes of southern Africa. The weight of evidence supporting this decolonising shift means that the landscapes of southern Africa cannot be read as natural ecosystems that were successively degraded by Indigenous peoples.

Figure 3

Land Taming as an Evolving Process of Agroecological Land-Case Practices on the Living Landscapes of Southern Africa



These insights reframe readings of how the practices of the Indigenous peoples of southern Africa were primitive, crude, and destructive to the environment. This demonisation of Indigenous peoples is found in early chitemene agriculture, which was taught as a destructive process of slash-and-burn contributing to biodiversity loss and soil erosion. Contrary to this colonial reading of early woodland farming practices, we now know that burning was a way of controlling soil fauna like armyworms, and releasing important nutrients in leached forest soils. There is also evidence of a cyclical use of forested areas with a long fallow period that allowed habitats to recover so that they could be tilled again (O'Donoghue et al., 2013). Further, this pattern of land tenure was a sustained cultural practice in the Miombo, where centuries of change *tamed the land* (Chigwedere, 2016) to shape a mosaic mix of open

woodland and savanna that came to support cattle, people, and the herds of wildlife that the colonial eye of ecologists attributed to nature.

In order to challenge these colonial inscriptions, we revisited genealogical records, where the development of a settled land for agriculture was described as land taming. A re-examination of the historical record highlighted how these seasonal practices evolved as diverse forms of bio-cultural land care (refer the circular model of process in Figure 3 for further details).

We thus explored how the current environmental crisis could be understood as an outcome of modernity, and the IKS topics we explored were developed around sustainable food production. This topic surfaced Indigenous heritage practices like *izalene* (composting), *imifino* (green leafy vegetables) harvesting, and other seasonal agricultural practices found in southern African cultural settings (see the IK practices in Figure 3). Cultural artefacts were used to start up story-sharing conversations that had been reframed within a cultural perspective, and which overturned and displaced the dominant discourses of colonial modernity with a love for Africa and being African in the intergenerational company of others.

Case Studies of Design Research Lesson Planning With Teachers

The three case studies reported here were undertaken in 2023 as an exploratory process of collaborative learning towards the inclusion of Indigenous heritage technologies and knowledge in lesson planning. It is important to note that South African classrooms are sites of multicultural learning with a knowledge-mediated curriculum that has yet to fully develop a plural and inclusive ethos at the level of knowledge. The current curriculum strengthening process is intent on this so we are finding ourselves working on both the uncovering of Indigenous African heritage and the inclusion of other cultural knowledge capital in multicultural classroom settings. In the food security and agroecological focus of our work with teachers, we found ourselves giving attention to plural knowledge practices against the backdrop of African historiographies on living landscapes and the sustainability challenges that now confront all of us in modernity.

Case 1: The Inclusion of IK in Lesson Design Work With Teachers

In 2014, the Fundisa for Change team thought that IK would be a popular addition to teacher education courses, so Soul Shava and Rob O'Donoghue (2014) were asked to write up a course text for the inclusion of IK in the primary school curriculum. This course material remained unused in a formal course for several years until teachers in the KwaZulu-Natal Midlands expressed an interest in IK. We did some informal work on Fundisa for Change courses in 2020 and then brought IK into a series of ESD courses and research activities with teachers between 2021 and 2023.

Across these courses, where we included a focus on IK, there was a high level of interest. Yet the teachers reported that they did not have the knowledge to include IK in their teaching. They also reported that including community knowledge holders had limitations and that local knowledge topics did not always relate well to the school subjects they taught. Many teachers also noted that some learners were not interested because they did not value heritage knowledge.

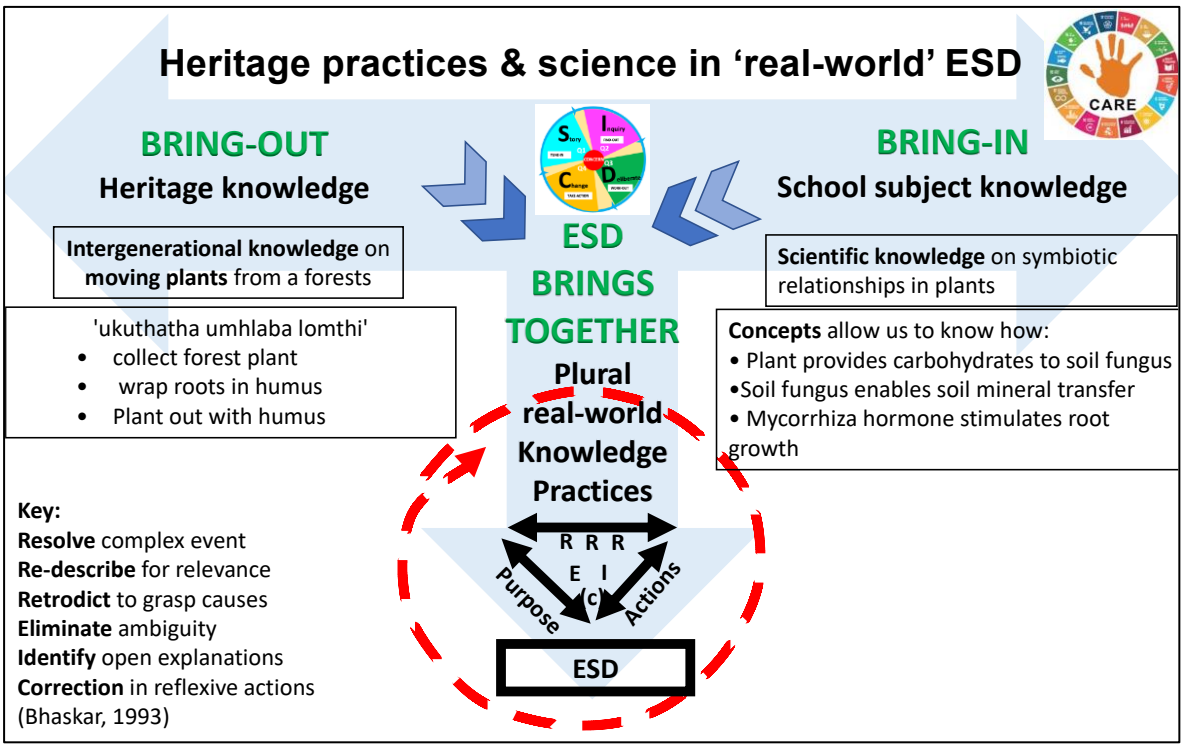
Therefore, in the courses, we used artefacts and accounts of Indigenous technologies and knowledge practices to support teachers in uncovering and recovering IK that had curriculum relevance. There was an enthusiastic response from teachers who set out to include IK in their lesson planning. This was our first formal design research experience on IK with primary school educators working in a diverse range of subject areas.

Outcomes

Contrary to the opposing of Indigenous and Western as differing epistemic processes, we found that in curriculum settings, the heritage knowledges related to real-world contexts of teaching and learning were not explicit because teachers foregrounded the concepts that needed to be taught and learned. We used a critical realist tool to review the contextualising and integration of knowledge in the real-world contexts of heritage food gardening. Here, our primary research interest was the interplay of heritage practices and scientific propositions. An exemplar of the analytical schema is provided in Figure 4. This is illustrated by the heritage planting of forest trees and the explanatory insights of modern scientific concepts related to mycorrhiza. Here, we used Bhaskar's (2016) RRREI(c) schema to enable an depth analysis of situated and expansive learning.

Figure 4

Critical Realism as an Analytical Tool Across Knowledge Systems



Bhaskar's dialectic critical realism comes with a reframing of the Hegelian dialectic around the identification and resolving of absences that render things incomplete and open to reframing. This insight and his RRREI(c) schema allowed us to juxtapose knowledges to create learning spaces where absence could be resolved and learning expanded. Notable here is how the ecological sciences have excluded people, and how these absences created ecology as an oppressive science until the recent advent of the environmental sciences, where the concept of people-as-part-of natural systems and processes opened up STEAM as an arena of learning to unlearn the practices that are incomplete and in need of revision. Using these tools, we were able to support teachers in planning lesson progressions for mediating learning across IK practices and the scientific propositions in the school curriculum, as shown in Figure 4.

Navigating through the process proved to be a daunting task. The lesson plans primarily focused on teaching about waste and topics related to school gardens. These became foundations for widening links with other curriculum content. Engaging with lesson plans in the sciences posed challenges because the knowledge presented itself from an external viewpoint comprising abstract concepts and processes to memorise. Confronted by these lesson design challenges, we encouraged teachers to work with heritage artefacts as a foundation for understanding scientific processes. Further investigation into this method is justified in future research. For recent insights on the integration of IK in STEM and transformative learning, refer to Godson et al. (2024), as well as the work by Lotz-Sisitka et al. (2015).

Notable here, however, is how the sharing of knowledge in their mother tongue enabled students to describe a heritage practice like *amasi* (souring milk) and how this opened up cultural similarities in the making of curds (in India) and yoghurt and relating these products with the science of fermentation. Once again, we saw that there was an accumulation of deep insights into cultural knowledges and that the sharing of these in the mother tongue brought richness and excitement into teaching and learning. In their lessons, teachers reported children working with IK practices in their mother tongue with simultaneous translation by another speaker of that mother tongue, allowing teachers to explore how this opened up the past, cultural pride, and depth of understanding across past, present, and future (O'Donoghue et al., 2021) as a learning pathway to knowledge-informed innovation.

We were also confronted by the challenge that cultural histories and knowledges other than Indigenous African knowledge needed to be included. This was particularly the case with the Indian knowledge heritage that developed historically in market gardening in the Durban area when indentured labour arrived from India. The historical record of oppression and struggle and the family histories of participants revealed that Indian peoples had learned about *imifino* from the Zulu, had brought their own wild herbs, and came to develop heritage knowledge for market gardening in the Durban area that reaches into the present day.

Insights

There was a high level of interest amongst teachers, but engaging modern learners was not always easy. Despite this, all cultures have heritage knowledge practices that can enhance the relevance of learning as well as stimulate respect for the past and a developing capacity for intercultural learning. We also noted that heritage practices and the modern sciences could be brought together in lesson planning in learning sequences that promoted interest and learning.

The inclusion of knowledge on *izalene* (litter management and composting) was particularly significant for waste management, with teachers reporting that learners were proud of and inspired by this Zulu heritage practice. Teachers noted that students identified with how creating artefacts from waste brought new sustainability challenges relating to plastics. Here, we noted that working with this knowledge practice and a wheel representing the Sustainable Development Goals (UNESCO, 2015) brought a sense of pride and enabled the students to link to health and well-being in the life skills curriculum (O'Donoghue et al., 2021). Across the courses, it was evident that the incorporation of Indigenous technologies and knowledge led to increasingly profound insights into the nuances of IK practices and how the neglect of heritage in curriculum settings was inhibiting learning with understanding, and developing pride and identity with being African, and having a developing love of Africa (Bhurekeni, 2021). The most significant revelations that came from the participating teachers were that the learners identified with their cultural knowledge practices, recognised diversity and cultural similarities, and developed an ability to see their knowledge in the world around them (O'Donoghue et al., 2021).

Case 2: Activating IK in an Online Teacher Education Course

Following the experience of working with IK practices and opening up the plural knowledge environment associated with this work, we developed schematic tools and exemplars that could be used to frame a teacher education course in STEAM curriculum settings. The Indigenous heritage materials and insights enable us to design a hybrid (contact and online) course for 37 foundation phase student teachers at Rhodes University. Its purpose was to explore cultural historical methodologies for surfacing IKS, associated learning theory, and analytical tools. Here, students worked with a series of practical kits around which we deliberated heritage knowledge as a foundation for story-sharing and small-scale social innovations to promote sustainable lifestyles and livelihoods related to local food gardening. This was supported by a monograph on early environmental work with IK (O'Donoghue et al., 1999) and a later work on Indigenous knowledge and social innovation (O'Donoghue et al., 2013). Figure 3 reflected the Nguni knowledge practices covered, and the student teachers explored how these knowledge practices could be deployed to restore family and community food gardening.

Outcomes

The student teachers raised concerns about the relevance of IK in our modern times but became engaged in how the colonial environmental narratives had maligned Indigenous peoples and marginalised their knowledge in curriculum settings. They worked well with IK in practical activities, and many began deliberations on the value of Indigenous practices to illuminate and engage the problems in the present day. After an initial scepticism about the value of IK in modern times, a wide range of restorative social justice and decolonising perspectives were explored. Here, the practical work on composting heritage and the natural sciences opened up a wide range of learning pathways that could be mediated with an IK foundation. Composting and *imifino* were particularly relevant because they related to anaemia (iron deficiency) in women, which has come with the modern diet.

Insights

This work began to affirm how heritage practices could be a foil for in-depth engagement on sustainability concerns in relation to livelihood and lifestyle practices. Much of the knowledge that surfaced in the story was expanded and related to local concerns through classroom deliberations and group tasks that were built into the programme. Because the programme was a STEAM teacher education programme, the student teachers did not develop specific lesson plans as in Case 1 but were challenged to use the heritage knowledge. This work affirmed the key role that conversation and deliberation played in the surfacing of knowledge and concerns that could be engaged with IK—work that was taken further with teachers in the KwaZulu-Natal Midlands by Lindiwe Ndlamlenze.

Case 3: The Deliberative Surfacing of IK With Teachers

Flowing from the development of online material and the experience of the earlier work with teachers on the inclusion of Indigenous heritage in lesson planning, we noted that one of the main stumbling blocks to the inclusion of IK in curriculum settings was the activation of Indigenous heritage amongst teachers and within school-in-community settings. Case 3 was a workshop with teachers in the KwaZulu-Natal Midlands, that was convened by Lindiwe Ndlamlenze and Rob O'Donoghue. Here teachers worked with artefacts to deliberate indigenous knowledge practices and their curriculum significance in the teaching of scientific concepts. Lindiwe's focus was to use artefacts to explore IK practices that could be included in the science curriculum. The topic she used to convene the workshop was, Separation of Liquids. Working with artefacts, we opened up food and nutrition topics beyond the food gardening scope of the first two exploratory case studies with teachers. The workshop task was for the teachers to develop lesson plans where IK practices could be used to teach the scientific process skills associated with the separation of liquids. Researching these processes with teachers was then taken up in Lindiwe's continuing academic studies.

The calabash was a notable technology that was puzzling to the teachers because they all knew *amasi* from their youth, but most now ate flavoured yoghurt in preference to the soured milk, and none soured their own milk at home. We opened with the story with an anecdote about how Nelson Mandela would eat *amasi* for breakfast and how healthy this was. We noted how he particularly favoured homemade *amasi* because it was more creamy and richer than that bought in a supermarket. It was a good conversation starter because many of the teachers recalled experiences from their youth, and the conversation developed as the calabash was passed around. We explored the practice of inoculating the calabash with yeast from the fermentation of sorghum, done with a special grass spoon that was used to gather the yeast froth in a small bowl for use in the souring of porridge. Everyone had stories to recount about soured porridge. This opened up insights into how the Nguni were masters of fermentation because they had developed their mastery over centuries of extracting nutrition from sorghum and millet. The conversation returned to *amasi* and the calabash as a fermentation chamber to which warm milk was added. The hidden element of the calabash technology in the fermenting of milk is a small hole in the lower side of the chamber. Before the milk is added, it is blocked with a small grass stem that swells when the liquid is added, and serves to seal any leakage. At this stage, we were able to pose the question: "Why is supermarket *amasi* slightly sour, whereas *amasi* made in the traditional way is smooth, sweet and creamy?" We came to the answer through conversation and demonstration of the separation of whey by tilting the calabash and allowing the liquid to drain out into a small bowl to be used for souring porridge. Working in similar ways, we looked at winnowing, the weeding hoe, and the lifting of ferments using the grass spoon.

Outcomes

The workshop affirmed much of the earlier work with teachers, adding substance to the articulation between Indigenous heritage practices and the acquisition of scientific knowledge as an expansive learning process in which work with heritage could be explored for its potential to enhance relevance. Following the workshop, the teachers did a curriculum analysis to identify how Indigenous heritage practices could become a foundation for enhancing the relevance of the science curriculum. Lindiwe supported and analysed this work as part of her as yet unpublished study on IK and science.

Insights

A key insight that emerged was how the heritage knowledge surfaced in conversation that activated and recovered shared fragments of memory that were then woven together in deliberative conversation. What also came to light was how an ethic of care and respect was embedded in the deliberative learning processes, a key outcome of research on Afrophilia conducted by Bhurekeni (2020).

Synthesis and Discussion

The three successive periods of work on heritage artefacts, technologies, and knowledge practices with teachers raised a range of questions that needed to be taken into account in our teacher education work to strengthen social learning in school-in-community settings. Here, ethics-led learning was a cross-cutting concern that surfaced in all cases and informed the reframing of the colonial narratives of exclusion and oppression. The work of John Bhurekeni (2022) was relevant here, notably his focus on Afrophilia—a shared love of Africa and love of self as an African. This was particularly notable in the affirming sense of identity, being, and pride that came with the overturning of colonial environmental narratives, and an African sense of belonging and land care associated with the living landscape of southern Africa as a heritage from which to contemplate more just and sustainable futures together.

Across the emerging case evidence and developing insights reflected above, we were able to begin to give attention to the diverse ways in which Indigenous heritage technologies and knowledge and life

experience were key processes to be considered for the strengthening of learning in curriculum settings within the southern African region. This allowed us to contemplate a deliberative schema for a school-in-community approach to the deliberative activation and inclusion of heritage knowledge in modern schooling and ESD

Conclusions

The use of the schematic research design tools enabled us to design the course to surface IK for start-up story materials for introducing science lessons in more culturally situated and historically relevant ways. The ESD learning progression bridged heritage and scientific knowledge with the inclusion of scientific process skills related to inquiry and data analysis, using a critical realist perspective. These and other outcomes of the exploratory research are being used to inform the design of an online learning programme for teachers. In this context, we discovered that a legacy of exclusion, and a favouring of everything modern, appear to be key drivers of how work with Indigenous technologies and knowledge practices situated in IKS have been slow to find their way into modern classroom and curriculum settings. There are many intertwined factors that can account for this, but none is currently giving adequate insights into how to work with IKs in the plural cultural settings of the modern classroom. The key insights emerging through this work we are doing with the teachers are that, with heritage knowledge, teachers are able to situate learning and enhance relevance in ways that enable learning-led change. This paper thus begins to uncover how the open-ended STEAM curriculum could be a key area where teachers will be able to work with Indigenous knowledge practices. This would require them to work with plural knowledges in learning transactions that recognise plural perspectives and practices. The study points to how teachers can recover and be enriched with IK insights, which they can use to create learning environments, and mediate insights that mirror how things were—and how things have changed. These processes can be a platform for STEAM innovation towards more sustainable ways of being and doing things together.

Acknowledgements

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