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Preface

The inclusion of Indigenous Knowledge Systems (IKS) in STEM education is a crucial step towards decolonizing knowledge and creating inclusive, relevant learning spaces that reflect culture. This book examines the theoretical, practical, and contextual aspects of incorporating IKS into Zimbabwe's STEM curriculum, with a focus on high school education.

The book is a reflection of the realization that education systems in postcolonial societies like Zimbabwe must do more than simply propagate traditional Western paradigms. The lived experiences, past events, and educational institutions of their society must be reflected on and informed by them. The rich Indigenous knowledge in Zimbabwe has played a significant role in shaping communities' understanding of agriculture, health, engineering, mathematics, and the environment over time. Still, much of this knowledge has been marginalized in formal education. By providing a framework for the meaningful integration of IKS into STEM disciplines, this work seeks to close that gap.

Indigenous Knowledge Systems are introduced in Chapter 1, detailing their origin, development, and philosophical basis. Chapter 2: An Examination of the current integration of IKS into STEM education in Zimbabwe, taking into account curricular approaches and classroom practice. Chapter 3 highlights the importance of evaluating and assessing integration efforts by proposing culturally sensitive and multidimensional approaches that are appropriate for Zimbabwean classrooms.

In Chapter 4, we explore the challenges and obstacles to achieving successful IKS-STEM integration, such as teacher readiness, epistemological tensions, and systemic resistance. Chapter 5 offers an exceptional examination of how Indigenous knowledge artefacts and practices can be utilized for conceptual development in high school STEM instruction, with practical examples from Zimbabwean communities being included in the analysis.

It is aimed at teachers, researchers and practitioners of decolonial education practices, as well as policymakers and teacher trainers, to develop locally relevant and globally relevant pedagogies. We aspire that this work will contribute to advancing scholarship that recognizes Indigenous knowledge as essential, living science and promotes African learners as both recipients and producers of valuable knowledge.

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Chapter 1: Introduction to Indigenous Knowledge Systems

1 Introduction

The rich, varied, and ever-evolving body of knowledge, abilities, ideologies, and worldviews that indigenous and local cultures have evolved over many generations is referred to as Indigenous Knowledge Systems (IKS) (Mapara, 2009). The communities that create these systems have strong cultural traditions, life experiences, and spiritual beliefs that form their foundation (Nyota and Mapara 2008; Ogegbo & Ramnarain, 2024). They represent the generational learning and creativity that has historically persisted, frequently in connection with particular social and environmental situations. Because IKS differs from community to community and reflects the diversity of human experience and ecosystem adaptation, it is not a monolith (Ogegbo & Ramnarain, 2024).

IKS is fundamentally community-driven and frequently disseminated verbally, through demonstration, and by involvement in the community (Mapara, 2009). Native agricultural traditions, traditional medicine, water conservation, weather forecasting, astronomy, architecture, navigation, metallurgy, ecological preservation, and mathematical patterns incorporated into music, art, and cultural practices are just a few examples (Mapara, 2009; Makwara, 2013; Maluleka & Ngulube, 2018). These integrative, adaptive knowledge systems are entwined with cultural and spiritual standards. They offer a useful and sustainable way to engage with nature, frequently demonstrating a profound ecological awareness that is consistent with current sustainability objectives.

Second, IKS can provide different epistemologies that encourage creativity and critical thinking (Govender & Mudzamiri, 2022). Students are more likely to recognize the importance of different viewpoints and get a more sophisticated knowledge of scientific inquiry when they are exposed to a variety of methods of knowing

(Matindike & Ramdhany, 2024). For example, although they are sometimes disregarded in formal science education, traditional herbal medical procedures include biochemical interactions, pattern recognition, and empirical testing that are similar to those in organic chemistry and pharmacology (Govender & Mudzamiri, 2022). Such activities can promote culturally appropriate career routes in science and pique students' interest in the biological sciences when incorporated into STEM education (Makonye & Dlamini, 2020).

Third, incorporating IKS into STEM instruction helps foster ethnic pride and inclusivity (Mapira & Mazambara, 2013; Makonye & Dlamini, 2020). When the STEM curriculum is exclusively centered on Western knowledge systems, it might feel alienating to many students, particularly those from underprivileged or rural backgrounds (Matindike & Ramdhany, 2024). By acknowledging and appreciating indigenous contributions to science and technology, we may increase student engagement and retention by fostering a sense of identification and belonging (Makonye & Dlamini, 2020; Govender & Mudzamiri, 2022). Utilizing IKS in the classroom can establish significant links between home and school knowledge, increasing the relevance and efficacy of education in Zimbabwe, where indigenous practices continue to play a significant role in many communities (Govender & Mudzamiri, 2022; Matindike & Ramdhany, 2024).

With its diverse range of ethnic groups, languages, and customs, Zimbabwe provides an ideal environment for incorporating IKS into STEM education (Chikodzi, 2022). Every tribe, including the Shona, Ndebele, Tonga, and Venda societies, has its own knowledge systems that are influenced by their cultural histories, spiritual beliefs, and interactions with the environment (Chikodzi, 2022). An example of astronomy and timekeeping is the Shona people's use of lunar calendars to determine agricultural cycles. The Great Zimbabwe civilization's traditional metalworking reveals their engineering and metallurgical expertise (Nyaumwe, 2006). Botany and pharmacology are demonstrated in action through the usage of native trees and plants for therapeutic purposes.

Furthermore, mathematics and logical thinking are frequently used into Zimbabwean storytelling, proverbs, and folklore. For example, number and sequence-based puzzles can teach basic math ideas, while classic games like nhodo, a pebble-based hand game, can improve counting, fine motor skills, and an awareness of chance (Sunzuma, 2018; Chahine, 2022). To make STEM education more interesting and rooted in students' real-world experiences, these cultural customs might be purposefully integrated into class activities (Govender & Mudzamiri, 2022; Matindike & Ramdhany, 2024).

IKS encompasses educational practices in addition to material. Indigenous education places a strong emphasis on group learning, environmental observation, apprenticeship, and hands-on involvement (Makonye & Dlamini, 2020; Matindike & Ramdhany, 2024). These techniques fit in nicely with inquiry-based and experiential learning approaches that are supported by contemporary pedagogical philosophies (Govender & Mudzamiri, 2022; Govender & Stott, 2024). These strategies can be used by educators to improve the way STEM courses are taught, encouraging students to develop their critical thinking, problem-solving, and teamwork abilities in addition to their cognitive comprehension (Matindike & Ramdhany, 2024).

2 Conceptualising STEM Indigenous Knowledge Systems (IKS)

A conceptual framework for comprehending the interactions between Indigenous Knowledge Systems (IKS) and STEM fields is offered by the IKS–STEM philosopical model (see figure 1.1). With its dynamic relationship to the five main components of IKS, ontological, epistemological, methodological, functional, and social & cultural the model places STEM at the center. Every component embodies a crucial facet of IKS, including its perspectives on reality, knowledge production, methodological application, practical applications, and integration into community life. The model promotes a comprehensive and inclusive approach to knowledge integration by putting STEM at the center and highlighting the mutual effect between scientific fields and indigenous ways of knowing.

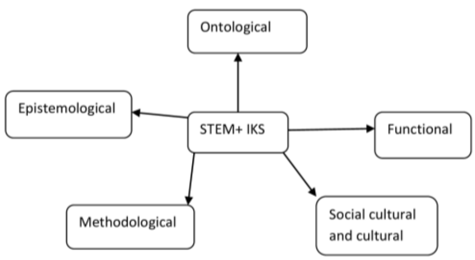

Fig 1.1 STEM-IKS Integrative Model

Ontological dimension

The fundamental ideas and perspectives that indigenous societies have regarding the nature of reality what is deemed real and how existence is interpreted are referred to as the ontological dimension of Indigenous Knowledge Systems (IKS) (Zinyeka, 2014). Indigenous peoples' cosmologies, worldviews, and spiritual beliefs are firmly anchored in this dimension (Matindike & Ramdhany, 2024; Govender & Stott, 2024).). Ontology in Zimbabwe and other African nations encompasses the spiritual, ancestral, and metaphysical spheres in addition to the material and physical universe. These viewpoints play a crucial role in how indigenous cultures understand natural phenomena, interact with their surroundings, and make decisions regarding their survival and day-to-day activities.

The conviction that all life forms are interrelated lies at the core of this ontological viewpoint (Nche & Michael, 2024). People are viewed as a part of a greater web of existence that encompasses ancestors, spirits, rivers, mountains, plants, and animals rather than as being distinct from nature (Nche & Michael, 2024). Rituals, taboos, and cultural standards that dictate conduct are common ways that this holistic awareness promotes harmony and balance between people and their surroundings (Govender & Stott, 2024). For instance, because of their alleged spiritual value or contribution to ecological stability, some plants or animals may be revered and safeguarded (Nche & Michael, 2024). These viewpoints support sustainability and biodiversity, which is in line with ideas in contemporary ecology and conservation biology.

Another essential element of this ontological dimension is the sanctity of life. It is believed that life is a gift from the Creator or ancestors and should be honored and protected (Mapara, 2009; Nche & Michael, 2024). The way resources are used is influenced by this belief system. For example, before planting or harvesting, traditional Zimbabwean farming methods frequently entail rituals to ask ancestors for their blessings (Magocha, et al., 2020). These actions support sustainable agriculture and ethical attitudes regarding land usage, thus they are more than just symbolic.

STEM education is significantly impacted by this ontological paradigm, especially in disciplines like biology, astronomy, and ecology. Indigenous groups have deep ecological knowledge of regional ecosystems, including seasonal rhythms, interspecies connections, and species behaviour (Haq, et al., 2023; Govender & Stott, 2024). Their knowledge of biodiversity and ecological balance, shaped by generations of careful observation and engagement with the environment, can offer important insights into conservation initiatives and plans for climate resilience.

The ontological understanding of interconnection in biology opposes Western science's frequently reductionist and mechanical methodology (Garcia-Olp et al., 2020). It promotes a more holistic view of living systems, in which human health is considered inextricably linked to the health of ecosystems, plants, and animals. The symbiotic link between humans and nature, for instance, is the foundation of traditional medicinal practices that employ plants and herbs (Maroyi, 2013). These traditions are frequently built on generations of empirical knowledge.

In IKS, astronomy is also closely related to both spiritual and agricultural life (Magocha, et al., 2019). For example, indigenous people in Zimbabwe have tracked time, performed rituals, and determined crop seasons using celestial observations (Mapara, 2009). The moon and stars are more than just celestial bodies; they have practical uses and spiritual meaning. Despite being distinct from contemporary astrophysics, these indigenous astronomical systems provide a rich cultural and scientific viewpoint on space and time.

The ontological aspect of IKS offers a fundamental perspective that is profoundly ecological, spiritual, and holistic (Nche & Michael, 2024). It provides a different perspective on the world, one that can enhance and support STEM education by establishing scientific research within morally sound, environmentally friendly, and culturally appropriate frameworks (Govender & Stott, 2024). Teachers and legislators may promote more inclusive and contextually aware scientific methods that connect with indigenous students and communities by embracing this dimension.

Epistemological dimension

Understanding how information is recognized, validated, and passed down within indigenous cultures depends heavily on the epistemological component of Indigenous information Systems (IKS) (Zinyeka, 2014). IKS are based on oral traditions, lived experience, observation, and community involvement, in contrast to Western epistemologies that frequently rely on formal education, abstract reasoning, and written record (Gumbo et al., 2021; Malapane et al., 2024). This dimension shows that knowledge in IKS is a dynamic, experienced process entwined with everyday life, society, and the environment rather than merely being a collection of facts or theories (Malapane et al., 2024).

Oral tradition lies at the heart of IKS epistemology, elders in many Zimbabwean communities transmit knowledge through songs, proverbs, rituals, and storytelling (Mapara, 2009; Garcia-Olp et al., 2020). These oral traditions are educational instruments that contain moral, agricultural, medical, and ecological lessons; they are not only entertainment (Malapane et al., 2024). Instructions regarding water conservation, planting cycles, or communal togetherness may be woven throughout a narrative about a drought (Magocha, et al., 2019). These tales strengthen knowledge throughout generations by being repeated and shared collectively, enabling it to change as necessary without becoming extinct (Malapane et al., 2024).

Another essential component of indigenous epistemology is observation (Zinyeka, et al., 2016). For instance, traditional Zimbabwean farmers use the positions of the stars, the behavior of animals, or the flowering of specific trees to forecast when rain will fall (Makwara, 2013). These are long-term, empirical observations that have frequently been gathered over decades or even centuries. They are verified by the constancy of results over time rather than in lab settings. The information is confirmed and disseminated when the same indicators result in the same weather (Makwara, 2013). This observational knowledge can be incorporated into contemporary STEM education and makes a substantial contribution to environmental science as a way to comprehend ecological connection and systems thinking.

In IKS, apprenticeship and practical experience also influence how knowledge is learned. Working with seasoned community members like farmers, healers, blacksmiths, and herbalists helps young people learn by doing (Madusise, 2019). Knowledge is embodied rather than abstract in these contexts. The senses, trial and error, and group correction and affirmation are the ways in which it is taught. A young apprentice learns the social and spiritual ideals related to the activity in addition to the technical skills of making a tool or making a herbal medicine. Such experiential learning is comparable to methods that have been demonstrated to improve conceptual comprehension and problem-solving abilities in STEM education, such as maker spaces, inquiry-based learning, and project-based activities (Govender & Stott, 2024).

Understanding soil fertility in Zimbabwe is a potent illustration of this epistemic dimension in action. Traditional farmers evaluate the quality of the soil using local indications, such as the soil's color and texture, the presence of specific earthworms or plants, and the yield of prior harvests (Materechera, 2008; Manyevere et al., 2020). The usefulness and applicability of this knowledge, which has been gathered over many generations of farming, are comparable to those of contemporary scientific soil analysis. By working the land together, sharing their observations and actions, and considering the results, farmers teach their children this knowledge (Materechera, 2008). Along with imparting useful skills, this learning-by-doing method helps students develop a closer bond with the land and its cycles.

IKS's epistemological component offers a convincing framework for STEM education that is based on lived experience, culture, and context. Teachers are able to connect formal scientific knowledge with indigenous methods of knowing by acknowledging and appreciating oral tradition, observation, and apprenticeship. STEM becomes more inclusive, relevant, and transformative as a result of this integration, which also enhances curricular content and affirms students' cultural identities (Govender & Stott, 2024).

Methodological dimension

The procedures by which knowledge is created, validated, and modified in indigenous communities are the focus of the methodological aspect of Indigenous Knowledge Systems (IKS) (Maunganidze, 2016). IKS are not static or unscientific; rather, they are based on a methodical engagement with the environment that has been refined over many generations via observation, experimentation, and real-world experience. This feature highlights the legitimacy and rigor inherent in the production of indigenous knowledge, highlighting significant similarities with the methodological underpinnings of contemporary scientific research.

The idea of sustained interaction with nature lies at the heart of this dimension. Indigenous peoples learn through long-term, intimate observation of biological activities, ecological patterns, and climate changes. They can spot reoccurring patterns, abnormalities, and cause-and-effect links thanks to their immersion. For example, Zimbabwean farmers have long used a complex system honed through centuries of environmental observation to determine the best times to plant, based not only on the calendar but also on clues from animal behavior, plant blossoming patterns, and weather variations (Makwara, 2013).

Trial-and-error learning is an essential methodological tool in IKS (Mandikonza, 2019). With this strategy, various methods or solutions to environmental problems are tested, effective practices are kept, and ineffective ones are changed or eliminated. This iterative process closely resembles scientific techniques like falsification and hypothesis testing. Indigenous societies use a collective method of gathering and analyzing data through memory, practice, and shared story, even though they do not use official recording or laboratory settings (Shapi et al., 2011). For instance, community agreement determines whether herbal remedies should be used or modified, and their efficacy is frequently assessed over time based on observed health results.

Another essential element of the methodological dimension is adaptation. IKS are dynamic by nature, changing in reaction to social, technical, and environmental shifts (Ngara & Mangizvo, 2013). Communities continuously modify their knowledge systems to account for changing conditions, including resource availability or climate unpredictability (Makwara, 2013). This flexibility guarantees IKS's durability and applicability over generations and emphasizes how well it meshes with creative problem-solving in STEM domains.

Indigenous fermentation methods provide a real-world example of this methodological sophistication. Microbial cultures are purposefully used in Zimbabwe's ancient methods of fermenting grains (like "mahewu") and milk (like "amasi") for preservation and better nourishment (Hove, 2015). These techniques are based on practical knowledge of fermentation processes ideal temperatures, containers, and timing—that are consistent with contemporary concepts of food microbiology, even if they are not described in terms of microbiological theory. In addition to being practical, these methods have been honed over centuries of experimentation, observation, and generational learning.

Likewise, indigenous agriculture's control of soil fertility has methodological depth (Hambati, 2022). Farmers gain sophisticated knowledge of soil properties, nitrogen cycle, and crop compatibility through extended land use. Sustainable farming systems are aided by techniques like crop rotation, legume intercropping, and the use of organic compost, which are informed by first hand knowledge of how the land reacts (Hambati, 2022). Important scientific objectives including food security, ecological sustainability, and biodiversity protection are supported by this empirical, evidence-based methodology.

A complex epistemological framework based on empirical observation, community validation, and environmental interaction is reflected in IKS's methodological dimension. It is a rigorous, flexible, and goal-oriented type of grassroots science. A more inclusive, locally based approach to scientific learning can be promoted, traditional and modern knowledge systems can be bridged, and cultural relevance can be improved by acknowledging and incorporating this dimension within STEM education, particularly in Zimbabwe.

Social and cultural dimension

Understanding how information is created, shared, controlled, and used within indigenous communities depends critically on the social and cultural component of Indigenous information Systems (IKS) (Shapi et al., 2011). According to Ndlovu, James, and Govender (2019) IK is grounded in epistemological understanding and that knowledge is a social construct. IKS are ingrained in a community's social structures and cultural practices, in contrast to the Western model of knowledge, which frequently emphasizes individual ownership, intellectual property rights, and official academic validation (Zinyeka, 2014). This community approach has significant effects on education, research, and innovation, especially in the context of STEM (science, technology, engineering, and mathematics) in Zimbabwe and other African civilizations. It also fundamentally changes the way information is created and preserved.

The collaborative aspect of knowledge ownership is at the core of the social and cultural dimension. The community as a whole or particular position within the community, such as elders, spiritual leaders, or traditional healers, are usually given credit for knowledge in indigenous cultures rather than a single person (Zinyeka, 2014). Through oral traditions, rituals, storytelling, and apprenticeship, this collective ownership guarantees that knowledge is maintained and passed down through the generations (Govender & Stott, 2024). The language, cultural identity, and social structures of the community are closely related to these behaviours (Chikodzi, 2022). For example, a lot of this knowledge is embedded in idioms, metaphors, and cultural expressions that might become meaningless when translated, making the preservation of indigenous languages essential.

IKS also differs from formal scientific paradigms in how knowledge is validated (Zinyeka, 2014). Indigenous knowledge is validated via historical continuity, practical application effectiveness, and community use rather than formal testing or peer-reviewed journals. For instance, generations of successful usage of particular medicinal plants to cure particular illnesses validate their use; this knowledge is protected by community standards and frequently kept hidden from outsiders to avoid abuse or exploitation (Zinyeka, 2014).

This is demonstrated in Zimbabwe through the employment of traditional medicinal practices, in which family members of healers or respected community elders pass along information about plants and therapeutic methods (Eglash et al., 2020). Eglash et al. (2020) reported that the use of traditional resources or artefacts must be approved by artists, elders or other representatives of the community, and must be brought to the students through the correct and appropriate cultural context to enable respectful use. Cultural taboos, customs, and deference to authority safeguard this information, which serves as a safeguard for intellectual property as well as a means of guaranteeing its responsible application (Ngara & Mangizvo, 2013). In a same vein, farmers frequently share traditional knowledge about crop rotation and soil fertility through experience, seasonal observation, and group experimentation (Manyevere et al., 2020). This kind of knowledge is flexible and dynamic, evolving throughout time in response to shifting environmental circumstances.

For science communication and ethical research in STEM domains, this aspect of IKS offers insightful lessons. It emphasizes the necessity of inclusive innovation tactics that refrain from extractive research methods and honor knowledge guardians (Shapi et al., 2011). IKS may unintentionally be marginalized or appropriated by Western modes of scientific inquiry and education because they do not acknowledge their cultural embeddedness or communal ownership (Hlalele, 2019). A culturally sensitive approach that honors the social contexts in which knowledge is situated is therefore necessary for incorporating IKS into STEM education (Mutsvangwa, 2023).

Recognizing IKS's social and cultural component inspires STEM researchers and educators to use more moral and interactive approaches to knowledge sharing (Ogegbo & Ramnarain, 2024). Informed consent must be obtained, research communities must be given back to, and indigenous contributors must be acknowledged as co-creators of knowledge rather than just study subjects. By doing this, STEM education can become more socially relevant, ethical, and inclusive especially in indigenous and multicultural cultures like Zimbabwe.

Functional dimension

The functional dimension of Indigenous Knowledge Systems (IKS) refers to the practical, action-oriented use of knowledge for the survival, sustainability, and well-being of communities (Madusise, 2019). Unlike abstract or purely theoretical knowledge, IKS is rooted in lived experience and aimed at addressing real-world challenges (Ogegbo & Ramnarain, 2024). This dimension underscores that indigenous knowledge is not merely historical or cultural it is a dynamic, utilitarian tool that communities actively apply to manage their lives and environments. Within the context of Science, Technology, Engineering, and Mathematics (STEM) education, the functional dimension of IKS holds great potential to foster context-relevant problem-solving skills and enhance learners' appreciation of the role of science in daily life.

Indigenous communities in Zimbabwe, as in many parts of Africa, have developed intricate systems for managing natural resources, agriculture, health, climate, and construction (Tanyanyiwa, 2019) These systems are evidence of deep empirical understanding of local environments, gained through centuries of observation, experimentation, and social transmission. For instance, traditional rainwater harvesting techniques such as the use of contour ridges, infiltration pits, and earth dams are responses to water scarcity in semi-arid areas of Zimbabwe (Ngara & Mangizvo, 2013). These methods, developed without formal engineering education, exhibit principles of hydrology and sustainable water management. Integrating such examples into STEM education not only validates indigenous practices but also illustrates scientific principles in real-life applications, thus enhancing the functional relevance of the curriculum (Madusise, 2019).

Indigenous understanding of soil fertility is another example (Manyevere et al., 2020). Physical indications like soil color, texture, the presence of particular plant species, or past crop yields are used by farmers in many rural Zimbabwean areas to assess soil quality and crop rotation patterns (Materechera, 2008; Manyevere et al., 2020; Magocha et al., 2020). Despite the lack of laboratory validation, these evaluations are frequently very accurate and have made it possible to provide food for centuries. An intuitive grasp of ecological and agricultural systems is demonstrated by the ability to read the land, modify planting plans, and apply organic fertilization methods like composting, mulching, or manure application (Magocha, et al., 2020). This information is in line with current soil science, but it also has the added benefit of being more economical and sustainable. Agroecological thinking, environmental stewardship, and locally grounded innovation can all be fostered by integrating these activities within STEM education.

Additionally, indigenous architectural practices including the use of locally sourced materials like clay, thatch, and timber as well as climate-adapted design—like temperature-regulating rondavels serve practical functions like environmental sustainability and thermal insulation (Nyaumwe, 2006). These methods use information from several STEM fields, such as environmental science (resource conservation), engineering (structural design), and physics (heat transmission) (Colijn, 2023). Students can gain a deeper understanding of energy efficiency and sustainable building concepts by learning and putting these methods into practice.

Conclusions

Critical implications for rethinking STEM education from the perspective of Indigenous Knowledge Systems are shown by the IKS–STEM philosophical model. The model highlights that knowledge is neither value-free nor context-neutral by centering STEM and encircling it with the ontological, epistemological, methodological, functional, and social-cultural aspects of IKS. In order to enable students, particularly those from indigenous and historically oppressed communities, to see their worldviews reflected and acknowledged in STEM curricula, it advocates for educational approaches that are contextual, culturally based, and inclusive. By including IKS in STEM education, pluralism in knowledge systems, critical thinking, and innovation anchored in local realities are all fostered. Thus, educators face the task of implementing thoughtful, transdisciplinary, and participatory approaches that enable students to make significant contributions to local and global issues. Finally, by acknowledging Indigenous knowledge as a legitimate, dynamic, and co-equal contributor to scientific research and technological advancement, this paradigm aids in the decolonization of STEM education.

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Chapter 2: IKS Integration in STEM Education in Zimbabwe.

1 Introduction

Indigenous Knowledge Systems (IKS) are the foundation for a transformative approach to STEM education, which involves integrating them into teaching. The realization that various knowledge systems, such as indigenous and Western scientific theories, can coexist and benefit STEM education in Zimbabwe is crucial for sustainable development. The chapter provide a comprehensive plan for meaningful integration of IKS and STEM that is culturally responsive, locally relevant and inclusive.

2 Proposed STEM IKS integration model

A comprehensive and inclusive approach to teaching and learning is offered by this framework for integrating Indigenous Knowledge Systems (IKS) into STEM education. Its foundation is epistemic pluralism, which respects Indigenous knowledge alongside Western science and values many ways of knowing. In order to successfully integrate, the framework emphasizes interrelated elements such as curriculum design, pedagogical practices, teacher education, community participation, assessment, and systemic support. Additionally, it places a strong emphasis on research and innovation to produce information that is culturally relevant. Through community-driven, locally relevant, globally responsive, and culturally grounded STEM education, this paradigm empowers students to actively contribute to knowledge and sustainable development.

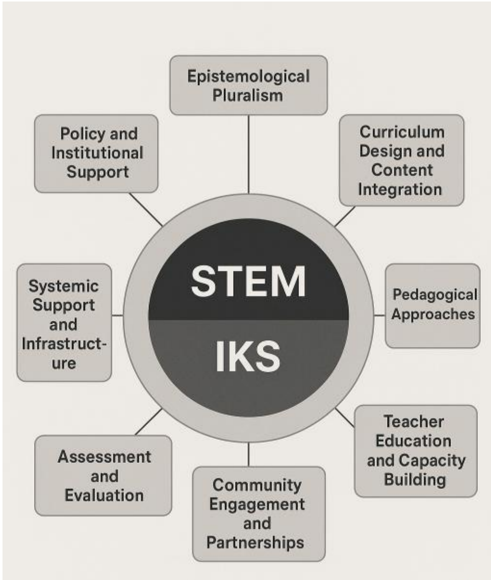

Figure 2.1 STEM IKS integration model

Epistemological Pluralism

Epistemological pluralism posits the existence of multiple valid methods for comprehending and understanding the world. Indigenous Knowledge Systems (IKS) are the key framework for integrating it into STEM education in Zimbabwe, providing a contextually grounded and culturally responsive education system. Indigenous ways of knowing have been sidelined or devalued in STEM education in Zimbabwe and other African countries over the centuries (Govender & Mudzamiri, 2022). As a consequence, the education system has become technically proficient but often disconnected from the actual experiences, surroundings, and cultural heritage of its intended audience (Govender & Mudzamiri, 2022).

Epistemological pluralism aims to identify and justify various knowledge systems, particularly those that have been historically underrepresented. Recognizing that indigenous knowledge, which is frequently disseminated orally and based on centuries of practical experience, has scientific value and real-world applications (Zinyeka, 2014; Mpofu & Vhurumuku, 2017). Indigenous weather forecasting techniques, sustainable agricultural practices, and herbal medicine are examples of evidence-based systems that have been refined over generations (Mapara, 2009). Instead of viewing these knowledge forms as secondary or anecdotal, they should be viewed as complements to contemporary scientific approaches.

Epistemic justice requires the integration of IKS and traditional STEM approaches. The notion of epidemic justice applies to both knowledge systems and their holders. It challenges the dominance of a single worldview, particularly the Eurocentric, positivist paradigm, which recognizes knowledge as only valid if it is objective, measurable, and replicable. Epistemological pluralism can facilitate STEM education in Zimbabwe, enabling it to become a cultural exchange center rather than merely transferring knowledge from one culture to another. This fosters critical thinking, mutual respect, and a more inclusive understanding of science as shaped by diverse cultures and worldviews (Eglash et al., 2020).

The integration of IKS within STEM is a response to the call for decolonising education (Makokotlela & Gumbo, 2025). Decolonisation in post-colonial Zimbabwe is not merely about rejecting Western knowledge, but also about creating conditions that allow indigenous epistemologies to coexist and thrive alongside others. The approach involves enabling scholars to examine scientific inquiries from diverse viewpoints, to recognize the local significance of global phenomena, and to perceive themselves as authentic contributors to scientific inquiry (Makokotlela & Gumbo, 2025). Cultural pride and sense of ownership are essential in forming learners' identities, making them proud to be born and raised, and encouraging educational engagement (Mapira & Mazambara, 2013).

The result of this integration is a curriculum that is inclusive and representative of Zimbabwean society, with varying cultures. Pluralistic teachings aim to ensure that cultures and lived experiences of students from rural, urban, and marginalized backgrounds are acknowledged and valued in the classroom (Hlalele, 2019). This allows for education to be used as a tool for individual growth and collective learning, as well as environmental awareness.

The establishment of epistemological pluralism as a philosophical foundation is not an abstract concept; it requires transforming education to establish it as the basis for equity, empowerment, and innovation. IKS and Western science are both important components of a Zimbabwean STEM education, which can enhance its relevance by equipping students with knowledge relevant to their local and global contexts.

3. Curriculum Design and Content Integration

Indigenous Knowledge Systems (IKS) can be integrated into STEM education in Zimbabwe, necessitating a systematic and deliberate approach to curriculum design and content. IKS is not viewed as secondary or incidental, but rather as a grounded and principled knowledge base that holds practical, scientific, and cultural significance. In this integration process, the key pillars are effective curriculum alignment and resource development (Makokotlela & Gumbo, 2025).

Curriculum Alignment

One of the initial stages in incorporating IKS into STEM education is to align indigenous knowledge with current learning goals (Mudaly, 2018; Gumbo et al, 2021). This permits a significant integration of historical and contemporary scientific understandings. Traditional water harvesting techniques, such as "madziva" (rainwater collection pits), can be integrated into environmental science research and applications like water conservation and hydrology. Zimbabwe's climatic conditions and resource constraints make these practices relevant to the country.

Ethnobotany, the traditional use and classification of plants, is a field that closely relates to the study of plant biology, medicinal plants (such as cannabis), and ecology in biology. Cultural understanding and scientific exploration can be integrated, allowing students to explore local herbal remedies and their active ingredients (Zinyeka, 2014). Similarly, indigenous engineering principles can be integrated with physics, including the use of animal-drawn cart mechanisms, traditional granary construction, and traditional blacksmithing (Nyaumwe, 2016). The examples serve as a foundation for abstract scientific concepts to be grounded in culturally familiar scenarios that learners can relate to and implement.

Teachers can enhance engagement by creating units and case studies that focus on local innovations and ecological practices. A case study on climate adaptation in rural areas could investigate the compatibility of old weather forecasting methods, such as animal behavior or plant phenology, with modern meteorological science. This could be useful. Cross-disciplinary connections can be made through case studies, which promote critical reflection and comparative analysis as well as pragmatic problem solving.

Resource Development

The integration of IKS into the STEM curriculum is heavily reliant on the use of appropriate teaching and learning materials (Govender and Mudzamiri 2022). The establishment of these resources requires genuine collaboration with indigenous knowledge holders, such as community elders and traditional healers, as well as artisans and farmers who are responsible for safeguarding this knowledge. Their involvement ensures that the content presented is truthful, authentic and contextually appropriate.

Textbooks and digital content must showcase the richness of Zimbabwean indigenous knowledge, utilizing stories, diagrams, and practical applications to convey scientific concepts (Sunzuma, 2018). In addition to textual content, it's crucial to incorporate visual aids like videos and animations or audio recordings, especially for oral traditions and practical demonstrations.

Including multi-lingual content is also important. The most suitable place to find many indigenous concepts is within local languages, like Shona, Ndebele, Tonga or Venda (in southern Africa Aboriginal peoples speaking the lesser pronounced English terms), as these have cultural and contextual meaning which may be lost due to translation (Chikodzi, 2022). In addition to improving comprehension, this linguistic integration reinforces the importance of students' own language and culture. The use of conventional metaphors, proverbs and analogies is also appropriate when explaining complex scientific concepts.

4. Teacher Education and Capacity Building.

Indigenous Knowledge Systems (IKS) are best integrated into STEM education in Zimbabwe, depending on the level of preparedness, awareness and attitudes of teachers (Sunzuma, 2018). As teachers who implement educational policy and curriculum, they must possess the knowledge and skills to provide culturally responsive and epistemologically inclusive instruction. Hence, teacher education and capacity building are essential components of achieving this integration.

Pre-service and In-service Training

The integration of IKS into pre-service teacher education requires a complete overhaul of curriculum in teacher training colleges and universities. It is important for trainee teachers to be familiar with the content of IKS, including traditional technologies, local ecological knowledge, and indigenous scientific practices, while also recognizing and effectively incorporating these learning elements into STEM classrooms. In course content, it is recommended to explore the intersection of traditional knowledge with modern science and encourage discussion and comparison rather than passive participation. The collaboration between curriculum creators, indigenous experts, and higher education establishments is essential.

Regular in-service training and Continuous Professional Development (CPD) opportunities should be provided to practicing teachers. These should be more than just isolated workshops, but also include a continuous professional learning journey. Programs for continuing professional development may encompass seminars with local knowledge, field trips and culturally sensitive teaching methods (Chitera & Moyo, 2021). The integration of academic and community knowledge through these initiatives enhances STEM teaching by incorporating local context into the classroom setting. Also, the training must address the issue of assessing students fairly using IKS-based materials, and ensure that evaluation methods consider alternative expressions such as +oral presentations or projects in community settings.

The importance of IKS as a genuine knowledge source is increasing alongside the need for teacher mentality. Education in Zimbabwe has historically been privileged and marginalized Western scientific paradigms, as is the case with many post-colonial societies (Chitate, 2016). Due to this legacy, numerous educators have adopted a hierarchy that devalues or disregards indigenous knowledge. Reversing this requires a deliberate process of attitude change.

Teacher training programs should promote reflective methods that encourage educators to reflect on their own beliefs, biases, and assumptions regarding knowledge. By involving community elders, indigenous scholars, and cultural practitioners in dialogues between schools, IKS can be used to bring about human connections within rural and marginalized communities (Hlalele, 2019).

If instructors recognize the breadth, accuracy and usefulness of local knowledge, they're inclined to engage students with excitement. The presence of ownership and respect is essential in promoting inclusive attitudes towards learners, leading to a learning environment where all knowledge systems are valued.

By providing teachers with the necessary resources and mindset, integration in IKS will be a holistic transformation that is not just theoretical. Teachers can use this opportunity to provide STEM education that is both locally based and globally inclusive, supporting the national goals of decolonization of education and advocating for sustainable development.

5. Community Engagement and Partnerships.

The integration of Indigenous Knowledge Systems (IKS) into STEM education in Zimbabwe is minimum within schools and formal institutions (Murwira & Higgs, 2023). Communities and partnerships are essential in ensuring that local knowledge systems are respected, authentically expressed, and effectively transmitted to students (Gumbo et al., 2021). Education is redefined as a collaborative enterprise where communities collaborate to create knowledge, rather than being solely dependent on external curriculums that are handed out (Ogegbo & Ramnarain, 2024).

Stakeholder Involvement

Local leaders, craftspeople, herbalists and farmers as well as elder members of the community can all play a role in getting STEM education grounded in real-life experiences (Gumbo et al, 2021). They are the guardians of Indigenous Knowledge, possessing insights that have been passed down through generations through oral traditions, apprenticeships, and observation (Murwira & Higgs, 2023). Through their involvement in curriculum design, teaching and assessment they guarantee the accuracy of IKS content while ensuring that it is culturally relevant and contextually appropriate (Ogegbo & Ramnarain, 2024).

Students can access a dual knowledge system by inviting elders and other knowledge holders to co-teach STEM topics or contribute to textbook content (Ogegbo & Ramnarain, 2024). The integration promotes the recognition of indigenous authority structures and fosters intergenerational learning. Furthermore, local leaders are instrumental in generating community support and justifying the educational process, ensuring that community members recognize the value of participating and supporting school activities.

Knowledge Documentation

The gradual erosion of traditional knowledge through modernization, migration, and generational disparities is a potential danger associated with the marginalization of IKS (Buthelezi et al., 2024). The preservation, documentation and transmission of indigenous knowledge in written form, oral form or digital form can be addressed by community-driven documentation projects initiated by schools and local institutions to counter this trend (Ogegbo & Ramnarain, 2024).

Participation in such projects is possible for students through activities such as interviewing older adults, documenting traditional practices, or accumulating herbarium collections of plants (Ogegbo & Ramnarain, 2024). In addition to cultural preservation, these initiatives are designed to provide students with the research and inquiry skills needed for STEM-based learning. The documentation initiatives are intended to enhance public knowledge and furnish physical resources such as IKS databases, storybooks, or local encyclopedias that can be integrated into the formal curriculum. The documentation must be conducted in an ethical manner, while respecting intellectual property rights and community consent, to avoid the risk of commoditization or extraction without benefit to the original owners (Buthelezi et al., 2024).

School-Community Linkages

For schools to truly engage in the dialogue between IKS and STEM, they must provide learners with structured opportunities to apply knowledge in real-world scenarios. Collaboration between schools and communities can be achieved through collaborative projects, field trips, local science fairs, and innovation hubs (Madusise, 2019; Chitera & Moyo, 2021; Ogegbo & Ramnarain, 2024). Students can either work with farmers to learn about traditional methods of soil conservation or work together with artisans to understand the physics of indigenous tools and structures (Gumbo et al, 2021). Through these activities, students can gain insight into the relevance of STEM education to their daily lives and immediate surroundings.

6. Assessment and Evaluation of IKS Integration in STEM Education

Indigenous Knowledge Systems (IKS) are well integrated into STEM education in Zimbabwe, with assessment and evaluation as key factors. While assessment methods are largely summative and uniform across disciplines, they often lack adequate representation of the entire spectrum of learning, especially when culturally embedded knowledge is taken into account (Chiwiye, 2013). Therefore, a novel method of assessment must be adopted to consider inclusivity, contextual relevance, and learner engagement. Hence, this requires the use of multi-modal assessment strategies, an emphasis on the contextual application of knowledge, and responsive feedback mechanisms.

Multi-modal Assessment

When integrating IKS into STEM education, it is essential to move away from writing exams and adopt more rigorous assessment approaches that recognize both conventional wisdom and scientific methods. Multi-modal assessment encompasses a range of approaches, including portfolios, group projects, performance tasks, demonstrations and case studies, as well as oral presentations (Guha & Roy, 2025). These methods enable learners to express their understanding in formats that are compatible with both indigenous and academic traditions.

An illustration is that a student could create an exhibition of their engagement with indigenous farming methods and compare them to scientific irrigation models. Conversely, learners may utilize oral arguments, potentially in native languages, to elucidate the medicinal properties of local plants and integrate botanical knowledge with cultural traditions. Not only do these approaches enhance comprehension but they also foster communication, creativity and critical thinking, key skills in IKS and STEM curriculum.

Contextual Relevance

IKS can be integrated with STEM to make learning more relevant in local settings. This is a key benefit of the system (Chiwiye, 2013). Evaluations must aim to gauge the ability of students to apply scientific concepts effectively within their communities. Educators can assess knowledge through projects that address local issues rather than abstract questions taken from students' everyday experiences.

As an illustration, students may be evaluated on their aptitude to design and experiment with a water purification process that incorporates indigenous and scientific elements. Developing sustainable housing solutions using indigenous materials and techniques may be left to others.' The assessments evaluate not just theoretical understanding, but also the practical implementation of knowledge, enabling learners to develop problem-solving skills that are culturally relevant.

Feedback Loops.

Effective integration of IKS requires the use of responsive and ongoing feedback mechanisms to support both teachers and students (Chiwiye, 2013). The use of formal assessment enables teachers to modify their teaching approach in real-time while considering student performance. It is crucial to emphasize IKS content, which may be unfamiliar to both learners and educators with Western pedagogical traditions.

Examples of feedback include peer reviews, when teachers meet with students, or community input from elders involved in the teaching process (Chiwiye, 2013). This feedback should be based on not just academic accuracy, but also cultural awareness and depth of understanding. The use of feedback to improve learning outcomes can also enhance student engagement with content and provide insight into the quality of teaching practices (Chiwiye, 2013).

In essence, assessment and evaluation in STEM education that integrate IKS must be dynamic, culturally relevant, and centered on the learner. The use of multi-modal assessment, the incorporation of evaluation in local contexts, and formative feedback loops can lead to an inclusive and empowering learning experience for educators in Zimbabwe (Guha & Roy, 2025). Besides improving educational outcomes, this also supports the wider objectives of cultural conservation and national advancement.

7. Policy and Institutional Support

National education and STEM policies must be integrated with cultural and indigenous knowledge preservation frameworks as part of an effective IKS-STEM integration strategy. In Zimbabwe, the education system follows the Zimbabwe National Curriculum Framework (NCF), which prioritizes a curriculum that is grounded in local knowledge and requires competency development. Including IKS in this framework promotes an inclusive and contextualized approach to learning.

Policy Integration involves the deliberate consideration of IKS as an integral part of core STEM curricula, rather than a secondary or optional subject. By adjusting curriculum guidelines, examination structures, and learning goals, they could incorporate indigenous perspectives, local knowledge practices, as well as problem-solving techniques (Chiremba, 2023). Units on indigenous engineering, traditional ecological knowledge, or local medicinal practices may be included in national science syllabi. Furthermore, the integration must be legally and administratively codified through the Ministry of Primary and Secondary Education, ensuring that all education authorities implement the change in uniform (Chiremba, 2023).

It is crucial to incorporate institutional structures when translating policy into action (Chiremba, 2023). The establishment of coordination mechanisms at various levels, including school, district, provincial, and national level, is crucial for the successful implementation of IKS-STEM integration. At the school level, each institution should establish an IKS-STEM Integration Committee comprising of educators, local knowledge holders, community elders, and learners. These committees would oversee the implementation, monitoring and assessment of IKS in STEM instruction.

District and provincial educational offices should appoint IKS coordinators who work closely with schools to offer pedagogical support, share best practices, and collaborate with local communities. A central task force or council under the Ministry of Education should be established to oversee policy implementation, teacher training, curriculum development, and evaluation frameworks on a national level. The education system is designed to promote coherence, quality control, and feedback mechanisms.

Funding and incentives that are appropriate must be provided in order to support policy and institutional efforts. Financial investment is necessary to support the development of teaching and learning materials, teacher training programs, community engagement activities, and local knowledge documentation. In rural areas, schools often lack the resources to innovate or expand their curriculum; therefore, targeted funding ensures that no school is left behind during the transition.

The use of incentives can also foster teacher involvement and innovation in IKS integration. Among them may be awards of recognition, career advancement opportunities or additional allowances for teachers who are involved in indigenous knowledge research and/or community collaboration. Schools that present successful models of IKS-STEM integration could receive a boost in grants or showcase their work at national educational forums. Additionally,

Finally, to integrate IKS into STEM education in Zimbabwe requires a comprehensive policy and institutional approach that balances curriculum goals with cultural preservation, create structures of governance, and provides the necessary financial and motivational support to effect systemic change.

8. Research and Innovation

To effectively incorporate Indigenous Knowledge Systems (IKS) into STEM education in Zimbabwe, strong research and a deliberate focus on innovation must be ensured. This double strategy guarantees that IKS is not just included in the curriculum, but also becomes a constantly evolving and changing body of knowledge that advances scientific comprehension as well as developing problem-solving skills and socio-economic development (Nwokocha1 & Legg-Jack, 2024).

The integration of IKS and STEM is largely dependent on evidence-based practice. This requires the systematic exploration and documentation of indigenous customs, their scientific validity, and their application to student education (Buthelezi et al, 2024). The rich cultural diversity and long-standing traditions of agriculture, medicine, metallurgy, and environmental management make Zimbabwe a favorable environment for research.

Teaching colleges and universities, particularly those focused on teacher training, should be encouraged to conduct multidisciplinary research that investigates the epistemological underpinnings of IKS and how it can be integrated with or supplemented with scientific concepts taught in STEM subjects (Nwokocha1 & Legg-Jack, 2024). Scientific methods can be used to evaluate the effectiveness and relevance of traditional weather forecasting techniques, crop rotation strategies, or indigenous architectural designs.

Furthermore, studies should focus on the outcomes of learners in classrooms where IKS is incorporated into STEM. This involves evaluating student engagement, understanding, critical thinking, and problem-solving skills. By conducting research, it is possible to provide empirical evidence on the advantages or disadvantages of incorporating local knowledge and guide pedagogical adjustments (Nwokocha1 & Legg-Jack, 2024). It empowers policy-makers and curriculum developers to make informed decisions based on contextual realities, rather than solely on imported models.

Qualitative studies, including interviews, focus groups, and ethnographic observation, should be included in an approach that considers community elders, traditional knowledge holders, as well as students and teachers. Their knowledge is essential in creating an education system that is culturally responsive and scientifically sound (Nwokocha1 & Legg-Jack, 2024).

The demonstration of the transformative potential of IKS-STEM integration requires practical innovation, not just research. The purpose of innovation incubators, particularly those located in schools and local communities, is to facilitate the real-time convergence of indigenous knowledge and scientific research.

It is recommended that these incubators support school-based projects, which recognize local issues and employ both indigenous and scientific approaches to address them. In order to address water scarcity, a rural school could initiate comparing traditional water conservation methods with modern irrigation systems through drafting and planning. The medicinal properties of local plants may be investigated using both ethnobotanical methods and biological assays by another.

Projects like these encourage hands-on learning and instill a sense of responsibility and achievement. In addition, they function as sites of communication between generations, where elders and local experts contribute to knowledge acquisition (Nwokocha1 & Legg-Jack, 2024).

Moreover, innovation centers can serve as hubs for knowledge sharing across regions or districts. There are also exhibitions, science fair and competition where students work on projects local to them. Such hubs promote innovation, foster problem-solving skills, and may result in scalable innovations that address more extensive developmental issues (Nwokocha1 & Legg-Jack, 2024). Through the integration of research and innovation in the IKS-STEM framework, Zimbabwe can produce a future workforce that is not only academically qualified but also culturally upstanding.

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Chapter 3: Assessment and Evaluation of IKS Integration in STEM Classrooms

1 Introduction

In Zimbabwe, Indigenous Knowledge Systems (IKS) are increasingly integrated into STEM education (Murwira & Higgs, 2023). The need to assess these systems is prompting a renewed drive to ensure they are culturally inclusive and respectful of diverse students. Traditional evaluation methods are inadequate in capturing the breadth of learning during IKS, particularly when it comes to knowledge gained through oral, experiential, and community-based means (Sunzuma, 2018). It is essential to have a robust and contextually responsive assessment and evaluation system to identify and address issues in STEM education. A robust assessment and evaluation system is essential for identifying problems and suggesting improvements in STEM education, as stated by Saxton et al. (2014). Incorporating Indigenous Knowledge Systems (IKS) requires the use of culturally grounded, context-aware, and pedagogically sound tools to assess learner outcomes in addition to measuring instructional practices (Onwu & Mufundirwa, 2020). Ball and Hill (2009) and Hiebert and Grouws (2007) all agree that evaluation in mathematics and science necessitates the alignment of assessment with instructional goals and classroom practice. The integration of IKS and STEM demands assessment systems to be established in a learning approach that incorporates various knowledge systems, encouraged inquiry-based instruction and emphasized learner involvement.

2.Assessment and Evaluation in STEM education

Potter et al. (2017) contend that assessment and evaluation processes in STEM should not solely focus on assessing students' content mastery, but also consider the quality and depth of students' engagement. Fan and Yu (2017) assert that STEM evaluation must incorporate skills such as problem-solving, collaboration, higher-order thinking, and other 21st-century abilities. When assessing IKS integration, these dimensions are equally significant, as Indigenous knowledge often emphasizes relational understanding, community relevance and the importance of problem-solving through lived experience. While assessment is a crucial aspect of STEM education, much research on the subject has concentrated on how teachers perceive and become aware of these teachers (Karakaya & Yılmaz, 2022). There are only a limited number of literature that explicitly mention assessment and evaluation practices in STEM (Karakaya & Yılmaz, 2022).

Akiri et al. (2021) report that teachers tend to use both traditional and alternative assessment methods, including project portfolios, experiment reports, open- and closed-ended questions, rubrics for evaluation, peer and self-assessment, and performance-based evaluations. The use of these tools is often inconsistent, and educators often lack adequate training in using them effectively, particularly in diverse and culturally mixed classrooms (Karakaya & Yılmaz, 2022).

In addition to this, Karakaya and Yılmaz (2022) recommend more dynamic assessment strategies such as observations, posters, concept maps and teacher-guided discussions. Assessment in STEM education is hindered by ambiguity in measurement objectives and reluctance to use context-appropriate tools (Karakaya & Yılmaz, 2022). Lack of proper training or access to diverse materials is among the reasons why teachers frequently misapply tools (Karakaya & Yılmaz, 2022). IKS integration amplifies the issues identified in general STEM assessment (Nkopodi et al., 2024). Karakaya and Yılmaz (2022) highlight systemic barriers that include inadequate teacher training, insufficient instructional time, lack of practical models, and institutional resistance to non-Western epistemologies. These obstacles impede the use of culturally sensitive assessment strategies that acknowledge and value Indigenous knowledge. Moreover, Saxton et al. (2014) have noted the lack of uniform measurement tools for the STEM context. The objective of STEM Education is to remedy this shortage by presenting a structure that can evaluate various aspects, including student performance and teacher proficiency. But even that approach needs to be adapted for local knowledge systems, languages and cultural contexts where IKS is present.

3. IKS based STEM assessment and evaluation

Written tests and standardized exams are the primary means of measuring theoretical knowledge and individual performance, which are considered traditional assessment tools (Rear 2018). These methods are based on Western educational systems that prioritize decontextualized reasoning, abstraction and aptitude for test-taking. These approaches may be beneficial for academic purposes, but they are insufficient in assessing the range of learning outcomes that arise from their application in STEM classrooms (Guha & Roy, 2025).

The concept of IKS encompasses a broad range of cultural practices, spiritual beliefs, and community life in varying ways (Mwapaura et al, 2024). Assessment and evaluation in STEM education demands more than just cognitive assessment. The approach demands the use of evaluation frameworks that reflect the practical application of knowledge by learners, their ethical engagement with communities, and their awareness within social and ecological contexts. It is imperative to develop flexible, inclusive and co-designed practice based assessment tools that are appropriate for teachers and community knowledge holders.

Contextual Understanding

Indigenous Knowledge Systems (IKS) can be integrated into STEM education to enhance students' ability to comprehend scientific concepts from a comprehensive perspective, while also reflecting their cultural and environmental context. In contrast to abstract or decontextualized learning, IKS integration necessitated assessment that prioritizes not memorization and instead evaluates learners' capacity for linking theoretical knowledge with local contexts, practices, and problem-solving techniques. By emphasizing the importance of a diverse range of cultural perspectives, students can understand science more fully through contextual understanding rather than limiting its focus to merely an abstract knowledge base (Gumbo et al., 2021).

To achieve success in this context, assessment must consider the level of familiarity among students regarding the interplay between Western scientific ideas and indigenous customs. To test for cultural diversity, students may be asked to relate the concept of photosynthesis to local agricultural practices rather than relying solely on technical language. The task may involve investigating companion plantations, sustainable soil management strategies, or the timing of crop rotations based on indigenous customs. Such assessments prioritize relational thinking and systems awareness, which are common traits in both STEM traditions and Indigenous knowledge traditions.

Furthermore, contextual understanding involves evaluating students' ability to relate STEM concepts to real-life issues within their communities. Teaching assistants can create assignments that require students to assess the efficiency of indigenous technologies, such as water harvesting systems, energy-efficient housing projects, or environmental protection measures, in relation to contemporary technological advancements. Comparative assessments can be structured as critical thinking tasks, research undertakings, or civic involvement investigations, enabling scholars to apply diverse epistemological perspectives in their analysis.

This approach not only fosters cognitive skills like analysis, synthesis, and evaluation but also cultivates cultural pride and relevance (Mapira & Mazambara, 2013). Learners' engagement with the curriculum is likely to increase when their cultural knowledge is integrated into formal education. Examples of assessment tools for this domain include reflective journals, analysis of case studies, oral presentations and visual storytelling methods that allow understanding across different cultures.

It is worth considering community involvement to enhance this process. Elders, local knowledge holders, and practitioners can collaborate in assessing students' contextual understanding, particularly in terms of the cultural accuracy and depth of their interpretations (Ward et al., 2023). Additionally, scholars can evaluate these texts using multiple approaches. This model is in line with indigenous values of communal learning and helps to facilitate intergenerational knowledge exchange.

Essentially, the evaluation of IKS integration in STEM necessitates multi-dimensional understanding of the context. It not only tests knowledge of the sciences, but also demonstrates how students can process and integrate different types of knowledge systems, apply their learning to local problems, and think critically about the relationships between science, culture, environment etc. Assessment is no longer a tool of judgment, but rather enables learning and cultural affirmation through co-learning.

Practical Application

Indigenous Knowledge Systems are based on practical application, which is grounded in lived experience, observation, experimentation, and transmission through direct engagement. Unlike many traditional STEM assessment methods, this is not. Instead, it relies on written tests and theoretical analysis. The assessment of IKS integration in STEM classrooms necessitates the use of assessment strategies that prioritize practical skills, community involvement, and hands-on learning (Zinyeka et al., 2016).

IKS is fundamentally experiential (Ogegbo & Ramnarain, 2024). Learning occurs not through passive listening, but through active participation in activities such as constructing traditional structures, preparing medicinal remedies, monitoring seasonal changes in biodiversity, and engaging in agricultural practices (Ogegbo & Ramnarain, 2024). The evaluation of STEM education through IKS should rely on project-based learning and performance assessments. The examinations can encompass initiatives like constructing indigenous tools, cultivating herbal medicine with scientifically grown medicinal plants, and developing sustainable technologies based on traditional innovations such as passive home cooling or gravity-fed irrigation systems.

There are several entry points provided by such projects to measure student comprehension. Teachers have the ability to assess not only the end product but also the method of student experimentation, which involves planning, teamwork, correcting errors, and refining concepts (Zinyeka et al., 2016). These methodical assessments are in line with the engineering design process emphasized in STEM education and reflect the iterative nature of indigenous innovation. It is important to collaborate with educators and community experts on developing rubrics for these tasks, in order that they respect scientific rigor while maintaining cultural authenticity.

Additionally, practical assessment tests can be created to foster interdisciplinary thinking. For instance, students may investigate a regional environmental problem such as water scarcity or soil erosion and present varying solutions that combine STEM knowledge with customary practices. They may conduct tests to determine the efficacy of soil additives like biochar or compost utilized in indigenous farming, or compare traditional and modern irrigation systems with regard to sustainability. STEM learning is centered around these investigations that promote systems thinking, data collection, hypothesis testing and cultural research.

Another rich aspect is the inclusion of community-based assessments. Elders or local practitioners could receive feedback on projects and ensure that they were culturally appropriate while also demonstrating practicality (Ward et al., 2023). This could be done by students through an online platform. These tests validate indigenous perspectives and guarantee that the knowledge acquired is grounded in practical experience. The teachings emphasize respectful participation and ethical inquiry, which are crucial skills for future scientists, engineers, and citizens.

Teaching also uses learning portfolios, which record the development of a student's work through sketches, photographs and reflections in the form of peer reviews. The integrated tests offer a more comprehensive understanding of student education and facilitate personalized instruction based on individual abilities and learning approaches. Additionally, peer assessment and self-assessment are also effective tools for metacognition and collaborative learning (Guha & Roy, 2025).

An analyzes of how IK is utilized in STEM classes necessitated a shift in both perspective and approach. Teachers must recognize different ways of thinking, have faith in academic learning that transcends traditional curriculum, and create assessments that acknowledge creativity, cultural significance. Through the use of genuine and inclusive evaluation practices, students not only demonstrate their content expertise but also contribute to knowledge production and community welfare.

Community Engagement

In Indigenous Knowledge Systems (IKS), the community is central to the transmission and validation of knowledge (Zinyeka, 2014). Unlike Western models of education which often confine learning to the classroom and individual achievement, IKS is collective learning rooted in place, culture and intergenerational exchange (Chitera & Moyo, 2021). So assessment of IKS in STEM classrooms must go beyond traditional academic measures and capture how learners engage with their communities as co-creators and co-learners of knowledge.

Assessment tasks can be designed to include community based projects, interviews with elders, participation in cultural rituals or documentation of traditional practices (Ward et al., 2023). For example students might be asked to do ethnographic research on traditional irrigation techniques, interview local artisans on material science in indigenous crafts or participate in food sovereignty projects using indigenous seed saving methods (Anor et al., 2022). These activities not only offer authentic learning experiences but also help students practice the critical skills of listening, observation, ethical engagement and synthesis (Zinyeka, 2014).

Evaluation criteria in such tasks should include both academic and cultural dimensions. Educators can assess how well students collect and interpret community knowledge, how well they adhere to cultural protocols (e.g. getting informed consent from elders or respecting sacred practices) and how well they synthesize local wisdom with scientific analysis. Rubrics can be developed with community members to ensure cultural nuances and values are considered in the assessment process.

Importantly involving community members such as traditional healers, indigenous scientists, farmers, artisans and elders as co-assessors lends legitimacy to indigenous knowledge systems and positions local knowledge holders as experts within the learning process (Anor et al., 2022) This not only validates student learning but also bridges the gap between formal education and community realities. It is believed that knowledge doesn't just reside in textbooks or institutions but also in lived experience and cultural practice.

Also this community based assessment approach gives students a deeper sense of ownership and relevance in their learning (Gumbo et al., 2021). By engaging with their own communities students see science not as an abstract foreign discipline but as something rooted in their heritage and daily lives. It also builds their capacity to be agents of change in their communities by applying STEM skills to local challenges in culturally meaningful ways.

Teachers should be provided with professional development and resources to support the design and facilitation of community based assessments. These should include ethical guidelines for community engagement, examples of culturally responsive rubrics and frameworks for collaborative evaluation that centre academic rigour and cultural relevance. So in short, community engagement in IKS in STEM education means we need to rethink what we count as evidence of learning. We need to value relational, experiential and collaborative knowledge making and see the community not as a passive setting but as an active living classroom.

Ethical and Environmental Awareness

Indigenous Knowledge Systems are often paired with contemporary STEM education as both schools emphasize ethics and the environment, but these concepts may be expressed differently. The principles of IKS center on the importance of interdependence, cooperation and sustainability, which shape human relationships with nature and others (Mpofu, 2022). Embedding these principles into STEM learning involves testing students not just for their technical skills but also because of their environmental and moral perspectives. The assessment and evaluation processes in STEM classrooms that incorporate IKS should include ethical and environmental awareness.

Many indigenous cultures view ethical behavior as closely tied to their relationship with the land, community and spiritual world (Makokotlela & Gumbo, 2025). The evaluation of student problem-solving skills based on sustainability, cultural sensitivity, and long-term impact can translate these values into STEM assessments. The effectiveness of a water filtration system designed by aspiring student may be evaluated in addition to compliance with local norms, environmental impact, and the potential for future use. Students working on renewable energy projects may be prompted to evaluate their cultural and environmental values in relation to the local community.

Tests can range from writing in reflective journals to presenting in a school environment or conducting sustainability audits as evidence of how well their work is evaluated and asked for changes. Ethical questions, such as "How does this solution affect local ecosystems?" or "Does this innovation align with the values of our community?" are all examples of ethical inquiries. By using rubrics that emphasize critical thinking, cultural awareness, and moral reasoning in conjunction with scientific accuracy and innovation, one can assess these reflections.

Furthermore, ethical awareness entails cognizing the obligations that come with knowledge, particularly in terms of intellectual property, cultural practices, and the respectful use of indigenous information (Mwapaura et al. 2024). As students engage with IKS, they must be encouraged to recognize that knowledge is not only a resource to be extracted but also embraced as an offering. Educators may employ tests that necessitate pupils to reveal their approach to ethical issues, whether in project reports, oral presentations, or collaborative exhibitions.

Teaching can lead to ethical engagement. The approach involves appropriately recognizing indigenous knowledge sources, co-developing evaluation criteria with community partners, and providing opportunities for students to learn from and collaborate with indigenous experts. Assessing assessment strategies should follow the principles of "two-eyed seeing," which recognize the merits and limitations of Western science and Indigenous ways of knowing (Onwu & Mufundirwa, 2020).

Moreover, in assessment, the focus on environmental awareness should be to promote systems thinking, which encourages students to see how scientific interventions affect ecosystems and generations. Long-term observation projects, environmental impact reports, and systems mapping activities could all be part of this (Zinyeka et al., 2016.

The inclusion of ethical and environmental concerns in the evaluation of IKS integration in STEM classrooms ensures that student learning advances beyond content mastery. It encourages responsible innovation, cultural humility and a greater sense of care for the Earth and its people. By doing this, it cultivates not only bright students but also dedicated stewards of science and society.

Assessment involves both affective and psychomotor domains

In order to incorporate Indigenous Knowledge Systems (IKS) into STEM education, assessment practices should be oriented beyond cognitive domain. Traditional educational evaluations have frequently emphasized intellectual performance, such as recall, formulating, or problem-solving abilities, while neglecting other crucial domains like affective and psychomotor performance (Guha & Roy, 2025). Nonetheless, IKS sees knowledge as holistic and embodied, with an emphasis on emotional engagement through discussion about values, and hands-on learning. Hence, an effective and culturally relevant assessment must incorporate robust methods for assessing both the individual and collective judgments.

Learner attitudes, emotions and motivations are the subjects of discussion in the affective domain (Guha & Roy, 2025). Respect for Indigenous knowledge holders, cultural diversity, embracing different ways of knowing and feeling responsible towards one's community as well as their environment are the key components of IKS

(Zinyeka, 2014). The qualities mentioned are not merely beneficial but also constitute fundamental aspects of learning that shape knowledge acquisition, interpretation, and utilization. Assessment in this area should aim to capture the internal development of students as they engage with Indigenous perspectives.
Reflective journals give students the chance to express their developing thoughts, feelings and emotions about learning about IKS. Students may share their memories of community elders, the impact of traditional stories on ecological relationships in a community context, or engaging with cultural activities such as festivals and planting trees. These journals can also offer insights into past experiences and practices (Guha & Roy, 2025).

Self-assessment checklists serve as an opportunity for students to evaluate their own behavior and mindset (Guha & Roy, 2025). These prompts may consist of statements such as "I listened attentively to knowledge shared by elders. I respected cultural beliefs different from mine, but collaborated respectfully with my peers during our group project." These tools enable students to internalize the values that form the basis for IKS and become more self-aware of their own development.

Peer feedback forms, their value are matched by their ability to promote community accountability and provide insight into interpersonal interactions during collaborative work. The group work behaviors of listening, sharing responsibilities, and valuing diverse opinions can be positively evaluated by peers through constructive feedback. Teachers can use this feedback to gauge their proficiency in developing the core competencies of empathy, respect, and teamwork, which are essential in both traditional IKS learning and contemporary STEM instruction. Teachers can establish a systematic approach to evaluation in the affective domain (Guha & Roy, 2025).
Rubrics allow for distinct descriptions of emotional and moral aptitudes. From demonstrating increasing awareness of cultural diversity to consistently recognizing and acknowledging Indigenous knowledge and perspectives, performance levels can vary.

Skillful Practice in the Psychomotor Domain and Embodied Learning

Psychomotor domain refers to learners' ability to perform physical tasks and manipulate tools or materials (Guha & Roy, 2025). IKS-informed STEM education places significant emphasis on this domain, as Indigenous knowledge is commonly acquired through experiential, embodied practices such as learning by doing, observation, and imitation. The psychomotor domain requires assessment strategies that are based on this framework.
Performance-based tasks where students can use their actions to demonstrate their understanding (Guha & Roy, 2025). As an illustration, students could be tasked with:
Build an imitation of a classic water harvesting structure, such as sand dams or trenches. Use native tools like grinding stones, weaving looms, or agricultural implements. Take part in conventional ecological tracking measures, such as

monitoring wildlife, identifying medicinal plants, or measuring soil quality using non-instrumental indicators. Build on indigenous architecture or create eco-friendly shelters using locally sourced materials, while maintaining principles of thermal efficiency and environmental harmony.

Educators should utilize this information when evaluating such assignments.
Rubrics measure dimensions such as precision which is the degree to which the student performed the task correctly. Process which is how well does the student follow through with steps, adaptable techniques to solve problems or find solutions? Safety which is how the student handled materials and tools in a responsible manner?
Observation checklists and video recordings are used in In outdoor or project-based settings, these tools can be advantageous in recording students' performance (Guha & Roy, 2025). These recordings can be re-watched by educators to examine skill development over time and offer personalized feedback. Additionally, involving community experts such as artisans, farmers, and healers can be included in the assessment process to add cultural value to the evaluation. By gaining insight into whether a student has followed traditional methods or handled sacred or sensitive materials, they contribute an important layer of authenticity and accountability.

4 Proposed Model for IKS STEM assessment and evaluation

STEM and Indigenous Knowledge Systems (IKS) are interdependent throughout the learning and assessment process, not competing or treated as separate frameworks (Ogegbo & Ramnarain, 2024). Through this integrated approach, scientific reasoning and traditional wisdom are valued, enabling learners to use a diverse range of knowledge to comprehend and apply it to real-life situations. Students learn to combine theoretical concepts with practical experience by utilizing IKS in STEM education, which promotes inclusive, locally relevant, and holistic learning (Ogegbo & Ramnarain, 2024). Through this integration, both cognitive depth and cultural relevance are enhanced, and creative thinking is encouraged by diverse knowledge traditions. Figure 3.1 shows a proposed model for IKS STEM integration assessment and evaluation.

Contextual Understanding

The degree to which students relate scientific concepts to local customs and traditions is evaluated by contextual understanding. Instead of teaching STEM through abstract means, this approach motivates students to comprehend the significance of subjects such as biology or chemistry in their traditional education, such that studying plant biology can help with healing, while also exploring seasonal patterns in traditional farming (Gumbo et al., 2021). STEM education is made meaningful, localized and responsive to learners' real-life situations as well as community knowledge systems.

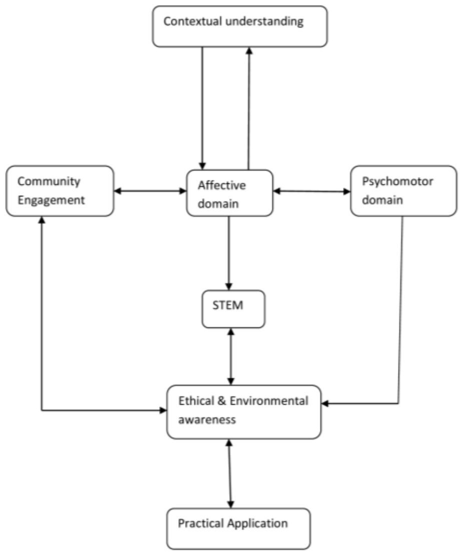

Fig 3.1 Model for IKS STEM assessment and evaluation

Community Engagement

It recognizes that education is not limited to the classroom and is enhanced by local practitioners such as elders, traditional healers; artisans, and farmers. Additionally, Community involvement in assessment through interviews, collaborative projects, and feedback from community members is crucial to maintaining the vibrancy and respect for IKS (Anor et al., 2022). It affirms the involvement of local voices in learning and fosters generational exchange. Not only are they evaluated for academic achievement, but students are also judged for their ethical interaction with communities, the collection and application of local knowledge, and the expression of sensitivity to cultural differences and respect.

Affective Domain

Both IKS and contemporary STEM education rely on the affective domain for measuring attitudes, values, and interpersonal skills. Accepting of indigenous knowledge, cultural awareness and diversity in the community (and thus their contributions to society) are part of this. Educators are advised to consider their own beliefs and biases, cultivating empathy and responsibility. Assessment methods like reflective journals, peer feedback and self-assessment checklists are also useful. This domain fosters the development of emotional intelligence, cultural humility, and ethical orientation in addition to academic excellence.

Psychomotor Domain

This domain is dedicated to assessing learners' physical and practical abilities, which are crucial in STEM and IKS. They evaluate students on tasks such as producing traditional tools, implementing indigenous ecological practices or conducting experiments that require precision and accuracy. Demonstrations and process-based rubrics are examples of performance-related assessment methods that assess not only outcomes but also technique, accuracy, and safety. In this domain, both learning-by doing and scientific practices like observation (such as measurement) and experimentation are respected, which is a hallmark of indigenous education (Ogegbo & Ramnarain, 2024).

Ethical and Environmental Awareness

This dimension assesses students' understanding of the ethical implications and environmental effects of scientific and technological practices. The emphasis in this domain is on IKS principles of reciprocity, stewardship, and respect for nature, while also motivating learners to critically consider sustainability, cultural sensitivity, or knowledge ownership. Impact analysis, environmental audits and ethical reflection in student projects are among the assessments. It's more than just technical ability; it'll also judge a student's capacity to make valuable, culturally sensitive and environmentally responsible choices in STEM-related tasks.

Practical Application

Practical implementation brings together STEM theories and IKS through practical applications (Ogegbo & Ramnarain, 2024). Engineering design processes and scientific research are utilized by students to tackle problems related specifically or directly to their communities, such as water purification, organic fertilization of crops, or energy conservation using traditional knowledge. Assessment centers on creativity, problem-solving, process, and innovation. The ability to integrate knowledge systems, use resources with appropriate planning and logical thinking, and develop solutions that are contextually relevant are among the criteria used to evaluate learners. It advances applied learning and validates indigenous innovation while fostering critical thinking that is relevant to 21st-century learners.

Conclusion

Redefining IKS within STEM necessitated a shift in our approach to measuring learning, taking into account the entire human development spectrum. Employing assessment strategies that incorporate the affective and psychomotor domains will enable teachers to better assess IKS-based competencies, such as emotional competence, moral awareness, cultural respect, and practical skill. By enhancing learning opportunities, these dimensions equip students to develop into responsible problem-solvers who understand their cultural backgrounds.

Assessment and evaluation play a crucial role in STEM education, particularly when Indigenous Knowledge Systems are being adopted. The complexity, richness, and cultural relevance of integration are often not fully conveyed by current practices. A revised approach must take into account the blending of diverse knowledge, emphasizes community involvement, and equip teachers with the necessary tools for effective evaluation.

It is advisable to prioritize co-creation of localized evaluation frameworks, building teacher capacity, and exploring innovative methods that reflect both scientific and Indigenous epistemology in future research and professional development. In STEM classrooms, assessment must adopt comprehensive and inclusive strategies to promote equity, authenticity.

Students can use Performance-Based Assessment to perform culturally relevant tasks and showcase their applied skills. The options may involve constructing models, replicating indigenous technologies, or addressing real-world issues through conventional approaches. A science unit that emphasizes sustainable energy can involve building solar cookers based on traditional Zimbabwean stoves, such as the tsotso. Equally, agricultural education could involve incorporating traditional techniques for organic compost production to blend ecological understanding with local practices. These tests validate local knowledge while enhancing STEM skills like design thinking and experimentation.

Oral Tradition and Storytelling are integral to the culture of Africans, including those from Zimbabwe. This is reflected in oral traditions. The assessment of learners' scientific knowledge can be facilitated by connecting them to indigenous technologies through these methods. For example, students might describe how the operation of a mortar and pestle illustrates concepts of mechanical advantage in physics. Chemists could explain the process and application of herbal cures, elucidating the scientific principles behind traditional preservation or treatment methods. This acknowledges cultural transmission practices and fosters the growth of communication and reasoning abilities.

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Chapter 4: Barriers to IKS STEM integration

1 Introduction

The integration of Indigenous Knowledge Systems (IKS) within STEM education is an essential component in establishing a more inclusive, contextually relevant, and cultural responsive educational system for Africa. IKS are a combination of centuries of experience, ecological knowledge, innovation, and community-based problem-solving that are in line with STEM education. While there has been a growing recognition that IKS is valuable, it continues to be largely disregarded in mainstream STEM curriculum and teaching practices. The absence of IKS is not due to its relevance or scientific value, but rather to various barriers that are deeply rooted in structural, epistemological, and pedagogical systems passed down from colonial education models. This chapter highlights the intricate issues that prevent the effective utilization of IKS in STEM instruction. Identifying these barriers is a vital first step in creating effective, long-lasting solutions. In the absence of action against the systemic deficiencies that persist in excluding IKS, attempts to diversify and decolonize STEM education could be seen as hopeless.

2. Epistemological bias

The presence of entrenched barriers in Zimbabwe and other African regions is a major obstacle to the incorporation of Indigenous Knowledge Systems (IKS) into STEM education (Shive, 2025). The central point of contention is the predominance of Western scientific paradigms, which define what's considered "legitimate knowledge" in education. These paradigms are based on enlightenment principles of objectivity, reductionism, empirical observation and quantification. Despite the significant impact of these principles on technological progress, their implementation is still ongoing. The establishment of an educational atmosphere has pushed aside alternative ways of understanding, particularly those that are based on African indigenous perspectives (Shizha, 2006).

In practice, epistemological bias is exhibited in several important ways (Zinyeka, 2014). Firstly, STEM curricula often lack explicit space for IKS content (Mlotshwa & Tsakeni, 2024). Science syllabi often adhere to Western academic boundaries of mathematics, technology, physics, chemistry, and biology without considering indigenous perspectives. In environmental science, where indigenous knowledge could be crucial, the curriculum typically emphasizes global concepts like carbon cycles, climate modeling, and renewable energy technologies, while neglecting local conservation practices, traditional weather forecasting, or ecological stewardship (Mapira & Mazambara, 2013). Students are unable to engage with the knowledge systems of their own communities during their education. Their understanding of science as a diverse and culturally varied activity is limited by this, as well.

Secondly, textbooks and other learning materials seldom make reference to local innovations or indigenous practices (Sunzuma, 2018). Western examples are frequently used to teach scientific and mathematical principles (Sunzuma, 2018). It is possible to impart mechanics principles through Newtonian physics and examples like elevators, cars, or European-style bridged bridges instead of traditional Zimbabwean grain mills. It is possible for chemistry classes to cover reactions with chemicals like hydrochloric acid and sodium hydroxide in the laboratory, without making any mention of these substances. Whether it's hand-burning waste from indigenous sources, traditional soap production, fermentation methods, or medicinal extracts.

This dearth of localization in teaching materials not only reinforces the belief that science is foreign and external, but also undermines some of the everyday knowledge practices practiced in rural and peri-urban Zimbabwe (Mapara, 2009). IKS is not incorporated into the assessment methods (Moyo & Ndlovu, 2023). They frequently emphasize abstract recall over contextual or experiential learning. Standardized examinations usually emphasize structured problem-solving, essay-style explanations and multiple-choice questions (Sunzuma, 2018). It is uncommon for students to be evaluated on their comprehension of indigenous ecological knowledge, practical community-based skills, or the ethical aspects of implementing knowledge. A student who can explain the cultural and biological significance of crop rotation using lunar cycles or traditional calendars may not receive any marks unless they frame the answer in scientific terms from Western agriculture or environmental science textbooks. In such cases, the student input from communities becomes inaccessible, rendering it useless in terms of academics. Not only affects their performance, they lose confidence in their own culture.

Adding to the problem, implicit hierarchy of knowledge systems promoted through current pedagogical practices (Moyo & Ndlovu, 2023). The portrayal of Western science as neutral, universal, and superior is often used, while IKS is frequently portrayed as subjective, local, undue, or backward (Zinyeka, et al., 2016; Moyo & Ndlovu, 2023). Education's hierarchy reinforces colonial legacies and promote a single perspective of advancement and modernity (Shive, 2025). The focus on preventing diseases may be secondary to their use by learners, who do not also consider the beneficial effects of traditional herbal medicine. This practice has been used for generations to treat illnesses with evidence of effectiveness. The inclusion of IKS in scientific analysis is often restricted to the cultural or historical domain. The split strategy maintains the belief that IKS is a historical trend and science is projected to be an extremely problematic combination.

The bias is also felt by teachers. The majority of individuals receive education from institutions such as universities and colleges that follow syllabuses developed in accordance with Eurocentric academic models (Moyo & Ndlovu, 2023). As a result, they may not have the expertise or pedagogical confidence to incorporate IKS into their STEM teaching (Mandikonza, 2019). Many may have internalized prejudices, which perceive indigenous knowledge as unscientific or inferior. Consequently, opportunities to incorporate community knowledge, such as inviting a local healer to discuss medicinal plants in physics or teaching geometry through traditional architecture, are often overlooked (Gumbo et al., 2021). Epistemological bias is not limited to the curriculum, but extends to educators' attitudes and practices, many of whom have been trained in systems that devalued indigenous knowledge.

There's also the challenge of educational policy and curricular rigidity (Matindike & 2024). National curricula, examination syllabi, and teaching guidelines are slow to adapt due to their central control. Despite policy documents making general promises for cultural inclusion or localized content. Curriculum developers are not rewarded for working with local communities, elders, or traditional experts. Furthermore, the stress of high-stakes assessments often discourages teachers from exploring alternative pedagogies, particularly those that require access to local resources, community partnerships, or interdisciplinary approaches. Instead of being a mandatory aspect of STEM education, IKS is considered an optional or non-essential element in this setting.

Based on the understanding that science is not a monolithic or culturally exclusive pursuit, it is the recognition of multiple knowledge systems Western and indigenous that may exist together, intersect and enrich each other. Instead of being against STEM, IKS provides a unique perspective. Scientific understanding must consider a culturally relevant, sustainable, and place-based aspect (Shive, 2025). The curriculum must include examples from indigenous cultures and challenge the assumptions that underlie current definitions of science, evidence, and knowledge.

3. IKS integration into STEM Education Faces Uncertainty Between Teacher Training and Confidence.

Zimbabwe's lack of teacher training and the resulting low confidence among educators in handling indigenous content has been a significant obstacle to the integration of Indigenous Knowledge Systems (IKS) into STEM education (Mashoko, 2022). The majority of educators in the education system have been trained primarily in traditional, Western-oriented STEM methods that emphasize abstract scientific theories, formal experimentation, and universal principles (Ward et al., 2023). While these approaches may be beneficial, they often neglect or actively exclude culturally rooted ways of knowing, leading to a separation between the curriculum and students' lived experiences. Thus, teachers lack the ability to bridge the epistemological gap between IKS and modern STEM, leading to apprehension and even resistance to incorporation of indigenous knowledge into their teaching practices (Sunzuma, 2018; Ward et al., 2023).

One of the main obstacles is that many teachers are unfamiliar with indigenous practices (Sunzuma, 2018; Mlotshwa & Tsakeni, 2024). The marginalization of IKS in formal education and teacher training institutions is a result of the historical processes of colonization, missionary education, and post-independence curriculum reforms that prioritized Western science (Murwira, 2022). This is due to these factors. Accordingly, educators from indigenous communities may not have been able to critically examine or validate their traditional knowledge in academic settings. This lack of familiarity poses challenges for them in identifying appropriate indigenous content, contextualizing STEM concepts within local knowledge systems, and acknowledging the scientific value embedded in traditional practices such as herbal medicine, indigenous engineering efforts to combat global warming, or ecological management.

A further issue is that there are no professional development schemes or in-service training specifically designed to help with the pedagogical integration of IKS Sunzuma, 2018; Mlotshwa & Tsakeni, 2024). The majority of teacher training colleges and universities in Zimbabwe don't consider IKS part of their science education curriculum. Indigenous perspectives and the methods required to teach them are seldom addressed in workshops, seminars, or continuous professional development (CPD) sessions. Therefore, educators depart from school without the necessary resources, guidelines, or confidence to implement IKS in STEM classes. Hence, people who acknowledge the value of indigenous knowledge may be unsure how to convey it without formal guidelines, instructional materials, or assessment models.

However, the fear of misrepresenting or marginalizing indigenous knowledge is often triggered by this uncertainty (Buthelezi et al, 2024). The possibility of teaching IKS incorrectly, offending the general public, or exposing students to controversial or culturally sensitive practices is also a concern for educators (Buthelezi et al., 2024). The presence of traditional knowledge in classrooms with multicultural or religious diversity can lead to disagreement between students and parents. This is particularly problematic for these groups. Due to the fear of incorrect content and lack of institutional support, many teachers choose to avoid indigenous learning and thus maintain their exclusion from the curriculum. The absence of clear direction, culturally sensitive teaching strategies, or access to community-based knowledge holders leaves teachers with minimal assistance in managing a complex educational environment.

Furthermore, the fact that numerous instructors are derived from an education system that historically devalued indigenous knowledge adds to the complexity. Zimbabwe's formal education system was shaped by Eurocentric principles during the colonial and post-colonial era, which often depicted African knowledge systems as substandard (Murwira, 2022). The ideological heritage is still present in the minds and perceptions of both teachers and students. These biases may cause teachers to unconsciously perceive IKS as less scientific or less rigorous than Western knowledge. Classroom practices that prioritize textbook learning over experiential, community-based education and abstract problem-solving over contextual innovation are indicative of a deep-rooted suspicion.

The structure of national examinations and academic standards reinforces unconscious bias, which seldom rewards the inclusion of IKS (Moyo & Ndlovu, 2023). . As a result of the pressure to ensure high scores on standardized tests, teachers are more inclined to concentrate on exam topics rather than overall syllabus content. This can be problematic for culturally or holistically focused subjects. The imbalance between curriculum goals and assessment practices hinders innovation and may lead to IKS integration being merely superficial tokenism rather than a true pedagogical shift. Personal boundaries, institutional restrictions, and external accountability measures that reward conformity to a Western-centric education model are all obstacles faced by teachers.

Moreover, without the presence of mentorship or collaborative learning opportunities, individual teachers who aim to integrate IKS into STEM often find themselves isolated (Mashoko, 2022). Educators have limited opportunities to exchange best practices, co-create culturally relevant teaching materials, or engage with indigenous knowledge holders in a sustained manner. This isolation reinforces feelings of inadequacy and discourages experimentation. Teachers may lack the confidence to teach IKS because they do not witness its effectiveness in their professional settings. This underscores the importance of systemic professional connections and community partnerships that can empower teachers to take bold steps towards curricular transformation.

The absence of teacher training and confidence is significant factors in the way students view IKS (Moyo & Ndlovu, 2023). If teachers steer clear of indigenous knowledge or treat it as supplementary rather than integral, learners are given implicit signals regarding the hierarchy of acquired knowledge. It can erode individuals' cultural identity, diminish their self-assurance, and hinder their engagement in STEM topics that are perceived as alien to their realities. In comparison, if educators teach about respect for IKS and incorporate it meaningfully in lessons, they convey to students that their heritage is intellectually valuable and relevant to global knowledge systems. This not only motivates the learners, but it also fosters critical thinking, creativity, and problem-solving skills that are grounded in practical experience.

The measures taken include modifying teacher education programs to incorporate classes on indigenous epistemtems, creating resource packs and lesson plans in collaboration with communities, and organizing teacher workshops that unite scientists, elders/educators in dialogical learning spaces (Moyo & Ndlovu, 2023). Additionally, Moreover, teacher professional development should be continuous, reflective, and community-based; this will allow educators to develop confidence as they push themselves towards novel pedagogical frontiers. Building the necessary capacity won't just improve the quality of STEM education, but will also make it more inclusive, locally relevant and transformative.

3. Insufficient policy and institutional support for IKS Integration in STEM Education

By incorporating Indigenous Knowledge Systems (IKS), STEM education can enhance the cultural responsiveness, inclusivity, and local relevance of its curriculum (Zinyeka, 2016; Matindike & Ramdhany, 2024). Additionally, IKS is an integral component to STEM instruction. Zimbabwe and various African nations are recognizing the significance of IKS in education, at least in terms of rhetoric. Drawing on indigenous knowledge is a common theme in policy documents to foster national identity, sustainability, and improving learning outcomes. Even with these verbal and written commitments, there is still a dearth of practical support for integrating IKS into STEM education. A significant gap exists between policy intent and implementation, with numerous institutional, structural, and systemic obstacles preventing progress.

The curriculum's structure is a fundamental problem. National curriculum frameworks, whether endorsed by ministries of education or curriculum development authorities, seldom provide explicit directives or detailed guidelines for the application of IKS in STEM subjects (Mashoko, 2022). The emphasis on cultural heritage or local relevance in general education policies is often viewed as ambition rather than implementation. Despite the absence of local innovations, traditional practices, or indigenous environmental knowledge from STEM syllabi, Eurocentric perspectives continue to dominate. Teachers are unable to provide any guidance or motivation to incorporate IKS into their teaching practices in science or technology subjects due to the absence of clear curriculum outcomes or content descriptors (Mudaly, 2018).

Additionally, the examination boards and assessment authorities that have a significant impact on teaching and learning are not aligned with the objective of integrating IKS (Mashoko, 2022). National examinations in subjects such as biology, chemistry, mathematics and physics are generally standardized with formal scientific content. The assessments are demanding and influence school rankings, student advancement, and university admissions. Additionally, educators frequently have to prepare for exams by only teaching relevant material and discarding unassessed areas like IKS. Despite efforts to incorporate indigenous knowledge into official assessments, it is still overlooked and disregarded in classroom practice. IKS may be seen as an optional extracurricular activity for teachers, students, and parents who are impacted by the examination system, rather than a fundamental part of scientific literacy.

The shortage of support from teacher training institutes is a further problem. Colleges and universities that provide STEM education often lack adequate guidance on engaging with IKS in a meaningful and effective way (Mudaly, 2018). Both teacher education programs for pre-service and in-class teachers still reflect the major epistemologies of Western science, often without any discussion about the philosophical origins, research methods or practical applications of indigenous knowledge. Thus, numerous educators arrive in classes lacking cultural proficiency, self-assurance, or aptitude to instruct IKS-based subjects. People who acknowledge the value of IKS may find it difficult to apply in their everyday lives, owing no to any educational models, materials or mentorship. Curriculum reform can be hindered by the lack of teacher preparation, and vice versa.

A further major issue is the allocation of funds and resources. It is important to allocate significant resources towards research, materials development, teacher training and community involvement in developing and implementing a curriculum that incorporates IKS into STEM subjects (Moyo & Ndlovu, 2023). Additionally it requires extensive investment from local communities. Unfortunately, the majority of education systems in Zimbabwe and other African countries operate on a tight budget with minimal adjustment for resources (Mashoko, 2022). The creation of content related to IKS is frequently viewed as subordinate or non-essential, such as field-based learning materials, oral histories documentation, video recordings of traditional practices, or the development of bilingual resources. In addition, the absence of infrastructure like labs that promote indigenous science practices, herb gardens, and maker spaces hinders schools' ability to offer hands-on STEM learning using IKS technology. This is problematic. Integration efforts in rural schools, where indigenous knowledge is deeply ingrained, are further complicated by the lack of basic educational resources.

Apart from budgetary limitations, there are also institutional inertia and bureaucratic divisions. IKS is frequently centralized in silos, such as Ministries of Education, examination councils and curriculum development units or universities and teacher training colleges where coordination may be limited or shared strategies. This can create challenges for both policy makers and educational institutions. It is possible for policies to be developed separately from those that are in place. The policy of incorporating IKS into a national curriculum lacks the necessary cooperation with teacher training programs or examination councils. This is insufficient to ensure effective implementation. Using validated indigenous knowledge in classrooms is becoming increasingly difficult for teachers due to the absence of national databases or repositories. IKS integration requires the development of cross-sector partnerships between educators, traditional leaders, scientists and cultural experts that are not supported by institutional frameworks at present.

Also, there is often a gap between formal education establishments and the communities that possess indigenous knowledge. Generally speaking, knowledge in schools is considered to be the hub of modern, formal knowledge, while indigenous knowledge is perceived as less formal and more domesticated, grounded in family or community contexts (Matindike & Ramdhany, 2024). The lack of institutional mechanisms to facilitate collaboration between schools and communities, such as co-teaching models, elder-in-residence programs, or community-based learning projects, results in a dearth of knowledge beyond the classroom. Policymakers have not yet devised systemic strategies to encourage community members to take part in curriculum development, teaching and assessment of IKS-related content.

The issue is compounded by the absence of monitoring and evaluation procedures for IKS integration. It is rare to conduct rigorous, large-scale evaluations of pilot programs or IKS initiatives to determine their effectiveness or scalability. The absence of data demonstrating how IKS integration affects student engagement, learning outcomes and community relations makes it difficult to support such large-scale policy changes or sustained funding. Therefore, the majority of IKS endeavors are small-scale, donor-funded, and disconnected from the national education agenda.

To overcome these challenges, a strong political will, inter-institutional cooperation, and innovative policy frameworks are necessary to recognize IKS as not just enduring cultural heritage, but also encompassing dynamism and diversity in the field of STEM education.

4. Resource Limitations and Documentation Gaps

The continuous documentation gap and resource constraints present a significant challenge to the effective application of Indigenous Knowledge Systems (IKS) in STEM education in Zimbabwe and other African nations (Buthelezi et al., 2024; Mwapaura et al., 2024). IKS is primarily defined as oral, practice-based, and deeply rooted in specific cultural, ecological, or historical contexts. Although a strength in its own right, this is problematic when trying to integrate it into formal, textbook-based education systems that prioritize standardized, written, and scientifically codified knowledge. The shift from community-based oral knowledge exchange to classroom-centered pedagogical structures presents a range of challenging issues that education systems have yet to fully address.

There is a significant absence of well-documented, peer reviewed, and curriculum-aligned educational content that accurately represents the richness and complexity of IKS in formally structured form for the formal education system (Buthelezi et al., 2024; Mwapaura et al., 2024). Indigenous knowledge is primarily transmitted orally, from elders to youth, artisans to apprentices, and healers to patients, often through rituals/farming or other communal activities (Buthelezi et al., 2024; Mwapaura et al., 2024). Teachers who are trained in formal STEM subjects face difficulties in accessing, verifying and adapting this information for classroom use due to the importance of this oral tradition on their identity and the sustainability of these knowledge systems. Teachers rely heavily on textbooks and officially sanctioned resources, but there is little IKS content in those materials (Sunzuma, 2018). Therefore, even teachers with a positive attitude can still not be convinced to integrate IKS into STEM lessons due to absence of content or pedagogical support.

Furthermore, the location-dependent nature of numerous IKS practices adds another layer of complexity (Mlotshwa & Tsakeni, 2024). Certain ecological zones, linguistic groups or cultural practices are often the basis for traditional knowledge. The practices for preserving food, using herbs, and collecting water differ significantly between the dry land areas of Matabeleland and the wetlands of Mashonaland. A single-size-fits-all curriculum approach cannot incorporate IKS due to its specificity. Nevertheless, national education systems are designed for universal applicability and uniformity, leading to a disconnection between local knowledge and national curricular frameworks (Mlotshwa & Tsakeni, 2024). In rural areas, teachers may be aware of local practices but find it challenging to integrate them with centralized syllabi and standardized testing frameworks that don't prioritize specific knowledge for context-specific learning.

Material scarcity is a problem that affects numerous Zimbabwean schools, especially those in rural or under-funded urban areas. IKS-based STEM practical work can be achieved by utilizing indigenous tools, locally grown herbs, traditional technologies, and community experts or artisans in specific situations (Mlotshwa & Tsakeni, 2024). The instruction of students on creating traditional soaps or herbal remedies would necessitate familiarity with local ingredients, equipment for preparation, and potential assistance from members of the community. Even so, the majority of schools lack these facilities. The use of community-based resources is not systematic, stored or distributed, unlike traditional science experiments that may rely on standardized kits or chemicals provided through the formal education system (Mlotshwa & Tsakeni, 2024). IKS practical work takes this approach to a different level.

The problems are compounded by the lack of organized assistance from major educational institutions. Examination boards, curriculum development bodies, and teacher training colleges have not typically provided guidance or support for the integration of IKS into STEM (Sunzuma, 2018). Although abstract references to "local knowledge" or "contextual relevance" are sometimes included in the national curriculum, they often lack specificity, examples, or corresponding resources (Mudaly 2018). Hence, teachers are obliged to interpret these vague directives without any clear guidelines on standards, assessment tools, or teaching methods. The delivery of IKS content is inconsistent, with students being superficially influenced by indigenous elements such as traditional farming or herbal medicine. This leads to a lack of practical exploration and participation in more experiential ways.

Developing and implementing IKS-based STEM programs becomes more complicated due to funding limitations. Financial investment is necessary for resource development, which includes producing IKS-informed textbooks, training teachers to teach in culturally responsive pedagogy, and creating school-community partnerships (Shive, 2025). In spite of this, the majority of national education budgets are already constrained, with a focus on infrastructure development, examination administration, or ICT progress. Integration of IKS into STEM education in Zimbabwe's socio-cultural diversity would greatly improve its relevance and effectiveness, but is rarely given priority in allocations of funding. Schools are unable to obtain the necessary resources, engage in local expert exchanges, or carry out field-based learning experiences that utilize indigenous knowledge without having designated funding for IKS initiatives.

Also, the current institutional infrastructure does not provide for the interdisciplinary, experiential, and community-engaged learning that IKS integration offers. The fixed schedules, rigid subject limits, and desk-bound pedagogy of traditional classrooms do not lend much credence to the fluidity and holistic nature of indigenous knowledge. Teaching water conservation through traditional knowledge would require collaboration between science and geography departments, coordination with local elders, and time for field visits to community water sources. Still, most schools are not structurally prepared for this type of learning. Physical infrastructure, human resources (like science labs), and administrative flexibility are not available to support such initiatives.

A lack of resources, support, and institutional clarity effectively paralyzes teachers and schools that may have the drive to incorporate IKS into STEM (Moyo & Ndlovu, 2023). The absence of tools, data, and frameworks for engaging communities necessitates innovation. If there is no top-down commitment to embedding IKS into curriculum, assessment, and teacher training, the responsibility will be disproportionately placed on individual educators who often lack the time, training or support to implement it effectively (Shive, 2025).

To address these issues, a coordinated national effort is necessary. Education policymakers must pledge to document and validate IKS that are relevant to STEM education. There is need to fund for ethnobotanical studies, collecting oral histories and creating peer-reviewed resources that are accessible to teachers. Teacher training programs must include modules on IKS integration so that educators can learn about the content and pedagogical strategies associated with teaching (Shive, 2025).

5. Ethical and Intellectual Property Issues in the Integration of IKS into STEM Education

Indigenous Knowledge Systems (IKS) are an important factor that allows for learning that is contextual and culturally relevant in STEM education. Yet it also brings forth a number of intellectual property and ethical issues that teachers, policy-makers and communities must navigate with great care (Mwapaura et al., 2024). The significance of IKS is heightened in Zimbabwe and other African countries, where cultural identity, spirituality, and communal values are integral to the process. Ethical considerations are not limited to administrative or technical issues, but also encompass the core values of cultural preservation, identity, and justice (Mapira & Mazambara, 2013; Mwapaura et al., 2024).

A significant ethical matter is the question of what happens next, risk of misappropriation or exploitation of indigenous knowledge (Shizha, 2006). Many indigenous people consider their knowledge, including those related to medicinal plants, agricultural practices, and cosmological systems, as sacred or proprietary (Zinyeka, 2014; Buthelezi et al., 2024). The knowledge is frequently passed down through family or community connections and is safeguarded by customary laws that differ from Western legal systems (Mapira & Mazambara, 2013; Mwapaura et al., 2024). Consequently, communities may be complicit in sharing certain aspects of their knowledge with outsiders or formal education systems (Buthelezi et al., 2024). This can make them anxious about the commercialization or misrepresentation of their practices, particularly when the knowledge is obtained without consent and used without proper attribution or benefit-sharing (Buthelezi et al., 2024). STEM education presents ethical dilemmas regarding the teaching of knowledge, its representation, and who benefits from it.

6. Educators themselves often lack guidance.

Many educators are not equipped to handle cultural preferences or engage in discussions with traditional masters and elders (Mudaly, 2018). They may be unaware of the appropriate knowledge to use in the classroom or the process of seeking consent. A lesson on medicinal plants may not adequately reflect sacred knowledge or disregard the spiritual essence of certain rituals or plants. Indigenous practices may be presented in an unintended way by teachers who exaggerate or dehumanize them, perpetuating stereotypes that do not contribute to the promotion of respect and understanding (Mapira & Mazambara, 2013).

Several IKS practices incorporate spiritual or ritual elements (Zinyeka, 2014). Formal education environments may be at odds with those that are typically secular or influenced by dominant religious structures. Local environmental knowledge systems may include traditional rainmaking ceremonies and ancestral consultation rituals, but they may be viewed as superstitious or inappropriate in school settings (Shizha, 2006). The conflict arises when it comes to balancing cultural exchange with school policies or parental expectations, particularly in heterogeneous or religiously conservative school settings. A fine line needs to be struck between cultural inclusion and institutional limitations for educators.

In addition, many traditional practices are location-specific, for instance the local ecology, language, and history of a specific community. This particularity makes it difficult to generalize such practices for use in national curricula (Sunzuma, 2018). A water-saving technique employed by the Tonga people in the Zambezi Valley may not be comprehensible or relevant to students in Matabeleland or Harare. Attempting to incorporate IKS into STEM education without an in-depth understanding of these contextual differences may oversimplify or distort indigenous knowledge. Managing content standards for examination or curriculum purposes without diminishing the richness and authenticity of knowledge is problematic.

Moreover, schools frequently lack the necessary resources and personnel needed to enable effective IKS-based instruction (Shive, 2025). Rather than using textbooks or the internet, indigenous knowledge is often passed down through practice and observation (Mapira & Mazambara, 2013). Yet most schools do not have the tools, herbs or artifacts they need to display these rituals. In the same way, very few schools have connections with practitioners who possess traditional knowledge, such as herbalists, artisans or farmers, who could offer joint instruction or facilitate practical education. When these resources are depleted, designing engaging, hands-on lessons that reflect the experiential nature of IKS becomes challenging. IKS's pedagogical potential is limited by the lack of material support, which may also result in its marginalization within the curriculum (Hlalele, 2019).

The lack of IKS resources that are well-documented and align with curriculum, further complicates integration (Sunzuma, 2018). While Western science is primarily described in textbooks, peer-reviewed journals and online platforms, formal documentation of indigenous knowledge is not common. The documentation available is usually found in academic theses, non-governmental reports, or oral forms that are not accessible to teachers. The lack of accessible and dependable resources hinders educators from planning consistent, assessable lessons based on IKS. Moreover, it prompts inquiries into the authenticity and quantitative assessment of IKS in formal education systems that use standardized tests.

Another significant barrier is the limited assistance from examination boards and teacher training institutions. Despite rhetorical support for incorporating IKS, few teacher colleges or professional development programs provide sufficient training to teach IK alongside STEM (Sunzuma, 2018; Mlotshwa & Tsakeni, 2024). Educators are limited to using traditional STEM assessments due to the lack of guidance from examination boards on how to assess IKS-based content, which fails to recognize the relational nature of indigenous learning (Mudaly, 2018). A discrepancy between the aims of IKS integration and assessment systems for measuring learning outcomes is evident.

Furthermore, limited funding and institutional infrastructure limit and execute STEM programs that are based on IKS. Often, schools allocate limited funds towards exam preparation, textbooks, and technology, neglecting community involvement or pursuing fieldwork. There are few opportunities for funding to hold workshops with elders, explore traditional farms, or purchase indigenous tools. In the absence of these resources, schools cannot sustain sustained integration of IKS and instead consider it as a secondary focus in STEM education (Hennessy et al., 2022). Incorporating indigenous content is impeded by institutional factors such as strict school schedules, inadequate field travel, and overloaded syllabi (Sunzuma, 2018).

For ethical engagement, it is necessary to acknowledge indigenous intellectual property rights, implement mechanisms for community participation in curriculum development and protocols for consent/benefit-sharing/attribution (Mapira & Mazmbara, 2013). The development of these measures with communities is crucial for promoting mutual respect and sustainable knowledge sharing (Eglash et al., 2020).

7. The intersection of modernity and traditional in STEM Education

Indigenous Knowledge Systems (IKS) are encountering significant challenges in incorporating traditional and modern forms of STEM education, particularly in Zimbabwe and other African countries. In addition to the historical legacy of colonial education systems that favored Western epistemologies, this tension is also rooted in the socio-economic aspirations and desires of learners and their families (Murwira, 2022). For many parents, students and teachers alike STEM education is a doorway to modernity and economic success; also an invitation to participate in the activities. In comparison, native understandings are often deemed inadequately scientific or unimportant in the context of modernity (Matindike & Ramdhany, 2024). The perceived disparity between IKS and modern STEM perpetuates ingrained stigmas that prevent the effective representation of indigenous perspectives in mainstream education (Gwekwerere, 2016; Hlalele, 2019).

The demand for high-stake examination scores in many urban and peri-urban locations reinforce the narrow definition of education. Success is often associated with proficiency in English, understanding of abstract concepts, and ability to interact with technological systems. The primary focus of the dominant educational narrative is on formal knowledge acquisition rather than community-based, experiential learning. Indigenous Knowledge Systems that are deeply rooted in the land, the body, and oral tradition are frequently overlooked or disregarded in this context (Gwekwerere, 2016; Hlalele, 2019). Practitioners assimilate these principles, frequently adopting the perspective that conventional knowledge is to be neglected in the pursuit of advancement. A student in an urban area who is proficient in reciting Newton's Law(S) using words may lack knowledge or comprehension of how river fishing practices embody complex ecological principles.

The internalized stigma is not limited to urban areas. The presence of indigenous practices in rural schools can discourage students from engaging with IKS content, fearing a perception of being less educated or uncivilized (Hlalele, 2019). In these settings, English is not only used as pedagogy but also as an expression of intelligence and modernity. When teaching involves the use of local knowledge, such as the medicinal properties of indigenous plants or the engineering behind traditional granaries, students may feel embarrassed or disinterested. The reluctance is frequently made worse by peer pressure and societal narratives that associate indigenous knowledge with poverty or backwardness. Thus, even if IKS is present and applicable, it may be turned down by learners who are trying to distance themselves from their traditional roots (Anderson et al., 2021; Hlalele, 2019).

This tension is further strengthened by the structure of formal education itself. It is common for national curricula to be designed in accordance with international standards and university entry requirements, which tend to emphasize abstract, decontextualized knowledge (Anderson et al., 2021). As a result, there is little incentive for educators to study indigenous knowledge that is not subject to examination. The primary significance of examinations in determining students' future progress results in an intense pressure situation, which may make teachers feel unmotivated to spend time on tasks or topics not directly related to exam preparation (Sunzuma, 2018). Rather than being beneficial, traditional knowledge is seen as a distraction in this context. When educators are pressed for tangible results, they may devalue IKS and reinforce the very attitudes that hinder its integration.

Furthermore, the separation between schools and local organizations amplifies this distinction. Traditional African societies integrated learning into their daily routines, with elders providing guidance, rituals observing, and communal experiences. Education has been institutionalized, meaning that learning has now moved from the community to classrooms, where it is governed by timetables and textbooks (Shizha 2006; Gwekwerere, 2016). Due to this separation, students frequently encounter two distinct knowledge systems: one at school, which is based on formalized Western science, and the other, that is grounded in lived experience and tradition in either the village or home (Shizha 2006; Gwekwerere, 2016). Instead of being encouraged to unite these worlds, learners are often left to choose between them. The duality in question can lead to confusion, identity conflict, and even alienation.

These strains are exacerbated by urbanization and globalization. Many young people are losing touch with the customs, languages, and knowledge systems of their communities as urban lifestyle becomes more prevalent (Shizha 2006). It is possible that a high school student in an urban setup may not have knowledge of indigenous tree names or traditional remedies. With the emergence of global media, social networks, and digital technologies, indigenous practices are losing their significance. This detachment makes it harder for educators to make meaningful connections between STEM subjects and local knowledge, even if they do. Teachers who have grown up in urban areas and lack exposure to IKS may not be able or willing to teach it or use it as a tool to connect with scientific knowledge.

Also, the rejection of IKS can be bolstered by economic pressures and desires to move up the corporate ladder. The parents may steer their children away from learning about or exhibiting indigenous knowledge, as they believe it will not result in formal employment or social standing. Additionally, in a world where qualifications are highly valued and unemployment is high, the perceived value of IKS in job markets is low. This utilitarian view of education undermines the need to acknowledge and value indigenous knowledge, as well as impedes efforts to create a more comprehensive and all-encompassing educational system.

A solution to the tensions is to shift the paradigm of education systems, positioning IKS not as a hindrance to modernity but as an integral part of promoting ecumenical and ethnocentric approaches to learning. This requires a revision of the definitions of science, knowledge, and learning. It's not a replacement of modern science with traditional beliefs; rather, it is about taking IKS into STEM and understanding that when we integrate different knowledge systems together they will complement each other positively over time at various levels within which we operate (Matindike & Ramdhany, 2024). Sustainable agriculture can be taught through the integration of modern soil science and traditional crop rotation practices based on indigenous calendars. Physics courses can cover topics such as Newtonian mechanics and the principles behind conventional irrigation or grain storage designs. New assessment methods that prioritize oral knowledge, teamwork, community involvement, and practical problem-solving are necessary for this integration.

8. Assessment Inequality in IKS-Integrated STEM Education

Indigenous Knowledge Systems (IKS) are a major obstacle to integration in STEM education due to the fundamental disparity between indigenous knowledge and current educational assessment structures (Hennessy et al., 2022). Unlike many other places, Zimbabwe's traditional assessment systems are predominantly focused on standardized testing. The main focus of these systems is on written tests that emphasize factual evidence, abstract reasoning, and individual performance. This approach may work for some aspects of STEM education, but it's not in line with the holistic, hands-on, and community-based learning processes that are hallmark of IKS.

Normated tests are intended to assess quantitative knowledge and tend to concentrate on cognitive domains rather than affective and psychomotor domain Guha & Roy, 2025). A biology exam may require students to identify the parts of a plant cell or provide chemical equations for photosynthesis. The examination does not and cannot assess whether the student comprehends how traditional agricultural practices, such as companion planting, reflect indigenous communities' plant growth cycles based on environmental indicators. The significance of contextual understanding in IKS is often overlooked in such assessments.

Additionally, IKS-based skills like storytelling, ethics, communication, indigenous knowledge, and art are seldom or never formally tested. The transmission of scientific and environmental knowledge within indigenous communities is heavily reliant on oral traditions. Nuanced understandings of medicinal plants, animal behaviors, weather patterns, and sustainable resource management are among the topics covered. Mainstream assessments are not inclusive of oral or collective expression due to their focus on text and intended for silent, individual testing environments. The outcome is a systematic failure to recognize competencies that are highly esteemed in indigenous cultures.

The core element of IKS, ethical decision-making, is not given enough importance in conventional assessment models. Often, indigenous epistemologies emphasize the importance of community, ethical engagement with the environment, and interdependence (Zinyeka et al., 2016. STEM-based projects, such as a solution to soil erosion through traditional terracing techniques, require students to comprehend the science and consider ethical considerations. In spite of this, customary evaluation models do not account for these elements, instead evaluating the solution's technical accuracy or theoretical refinement without considering its cultural suitability or social viability.

Moreover, the physical aspects of IKS are essential to learning (e.g. creating tools; use of indigenous measurement systems; seasonal agricultural cycles); but not from formal assessment structures. Only short essays or multiple-choice questions can address skills related to the hands, body, and environment. It is possible to use practical demonstrations, community projects, and portfolio-based assessments more effectively (Zinyeka et al., 2016, but they are not commonly integrated into national assessment frameworks. Therefore, pupils who demonstrate proficiency in practical and community-based education settings may be disadvantaged in official assessments, and their complete potential remains unknown.

The need for teachers to "teach to the test" amplifies this mismatch. In a high-stakes examination setting, where students' performance is the sole factor that determines whether an individual or their teacher can teach, there are few alternatives to explore other content or assessment methods. It is common for teachers in resource-limited schools to prioritize exam-related topics, while neglecting non-tested and contextually relevant content such as IKS. Even if teachers are willing to integrate indigenous knowledge into their teaching, the lack of assessment alignment limits them (Sunzuma, 2018). Often, they have to compromise on their relevance and cultural authenticity in exchange.

Besides, learners acquire knowledge of the evaluation's principles. Learning may become less relevant to learners who prioritize indigenous knowledge over official or non-official knowledge in classrooms with a focus on IKS and not on final exams. Not only does this undermine the aim of including IKS in the curriculum, it harms cultural pride and identity as well (Mapira & Mazambara, 2013). This indicates to students that the knowledge of their communities and elders is not valuable in terms of academic or professional value, which reduces generational dissemination.

This misunderstanding affects equity and access as well. Rural indigenous students typically possess extensive cultural background, experiential abilities, and a deep understanding of environmental issues. They also demonstrate strong commitment to learning through their peers. On the other hand, the standard assessment system often does not recognize or reward these competencies, instead favoring students who are more proficient at abstract reasoning, academic English, and rote memorization. Uneven playing can lead to achievement gaps that are not based on skill but rather on cultural significance of assessment methods.

To address this, it is necessary to fundamentally change the way learning is measured and valued in order to correct misalignment with assessment. Firstly, the assessment tools being expanded to include performance-based evaluations, portfolios and oral presentations as well as community-engaged projects. For instance, in a biology evaluation, it could involve identifying nearby medicinal plants, providing an explanation of their uses through interviews with locals, and conducting basic scientific experiments to test their effectiveness. Culturally sensitive rubrics for such tasks would also need to be established, with criteria assessing collaboration between, ethical awareness of, contextual understanding and craftsmanship.

Additionally, assessment frameworks that incorporate IKS need to be co-developed by examination boards and curriculum developers with communities, educators, and indigenous knowledge holders. The options available may involve incorporating indigenous knowledge and practices into standardized tests, or creating individual modules and certificates that assess IKS-related skills.

Modules on culturally responsive assessment must be included in teacher training and professional development programs (Mlotshwa & Tsakeni, 2024). Teachers must possess the ability and aptitude to create, implement, and assess alternative assessments that reflect both STEM rigor and IKS principles. Their ability to manage classroom time and resources effectively is crucial for balancing exam preparation with hands-on, IKS-based learning experiences.

Reform at the policy level is necessary to incorporate IKS into national assessment systems formally. In addition to curricular changes, there is also investment in assessment infrastructure such as the creation of digital platforms for portfolio submissions, culturally responsive evaluation training for external assessors and recognition of IKS-based qualifications in tertiary education and employment.

9. The Fragmentation Between Schools and Communities

Integrated in community life is one of the strengths of Indigenous Knowledge Systems (IKS). Instead of being an abstract or categorical set, IKS is a living and evolving knowledge system that has been passed down through generations through oral traditions in the home (closed spaces), through apprenticeships, communal observation, through storytelling, as well as through daily rituals and practices Zinyeka et al., 2016). Its knowledge is highly contextual, often embodied in local language, symbols and through environmental interactions. Furthermore, it's highly ethical and relational, based on mutual respect, reciprocity, or even shared responsibility (Eglash et al., 2020). In Zimbabwe, the integration of IKS into STEM education is largely hindered by the ongoing challenge of maintaining strong national and international student engagement.

The national school calendar dictates standardized timetables for formal education, which include fixed terms and lesson periods, as well as established examination schedules. In comparison to other subjects, indigenous education is typically structured around a particular sequence.

Seasonal and cyclical rhythms, such as rainfall patterns, planting seasons, animal rituals, or migration dictate how knowledge is transmitted, whether it occurs during specific times of the year or under specific lunar conditions. The absence of these ecological rhythms in the formal school system means that students often miss out on learning opportunities that are culturally and environmentally situated. Indigenous practices that require community participation and time-based engagement are frequently disregarded or interfere with by school schedules.

The temporal disparity is compounded by the dearth of institutional means for schools to engage with local knowledge holders. Many communities have a wealth of indigenous knowledge, but educational institutions seldom provide formal chances for these individuals to make significant contributions to teaching or curriculum development. Communities of knowledge experts are typically not recognized as having received formal credentials from the education system, unlike those who receive textbooks or certified teachers. Additionally, there is typically no policy framework that permits teachers to invite community members into classrooms as co-educators. The exclusion reinforces the idea that IKS is not a significant or valuable subject, especially when compared to STEM education, which is still viewed in reliance on laboratory science and technical accuracy rather than on actual knowledge.

Many young people, particularly in urban areas or with the rise of globalization and digital media, consider traditional knowledge and its enslavers to be outdated or non-relevant (Sunzuma, 2018). Younger individuals may exhibit disrespect or lack interest in societal norms and values, as perceived by their older counterparts. Mutual indecision weakens the natural pathways that IKS has traditionally been transmitted through. If schools are not utilized as intermediaries between generations, knowledge transmission will be exacerbated. Socializing students into a formal education system prioritizes individual success and standardized testing, while neglecting the communal, oral modes of learning.

Education is dominated by high-stakes exams, which place great demands on both teachers and students to concentrate upon measurable content in written tests. IKS-based competencies is uncommon for formal settings to evaluate activities like oral storytelling, ethical reasoning and social responsibility. Other methods of assessing these skills, such as observation (as the most common assessment tool), portfolio evaluation, and peer review or community feedback are not commonly used in the formal education system. Therefore, educators are frequently compelled to administer tests and neglect important, communal topics that are not examined.

Also, numerous educators feel inadequate or unenforced in integrating IKS into the STEM curriculum. Their inability to create curricula that is culturally sensitive may be due, along with a lack of training, resources and confidence, or concern over misrepresentation of sacred or sensitive knowledge (Matindike & Ramdhany, 2024). Even if there are clear guidelines and collaborative models, it is possible for educated individuals to avoid engaging with IKS.

Teachings from textbooks and laboratories reinforce the notion that authentic knowledge is not handed down by grandparents or local ecosystems (Shizha, 2006). The growing disparity between schools and communities necessitates actionable steps to bridge this divide. It is crucial for schools to acknowledge that communities are not just recipients of education, but also rich sources of knowledge and pedagogical expertise. One approach is to establish.

Through the use of both STEM techniques and indigenous approaches, students collaborate with local experts to address real-world issues (Chitera & Moyo, 2021). A water purification project could combine scientific principles of filtration with conventional methods involving plant materials and clay. Such activities not only contextualize STEM learning but also serve to validate the cultural heritage of learners.

Elders could aid in assessing students' knowledge of herbal medicine, while artisans could evaluate their practical abilities in crafting or designing (Ward et al., 2023). Memoranda of understanding between schools and local cultural institutions or elders' council can be used to formalize these partnerships. Furthermore, teacher training programs need to be restructured to include modules on IKS, community engagement, and culturally responsive pedagogy, which will equip educators with the confidence and ethical principles needed to create integrative learning environments.

It is necessary for education policymakers and curriculum designers to also create content flexible structures allowing for seasonal learning, interdisciplinary projects, and diverse assessment methods. It is important to allocate space for reflection journals, storytelling during interviews, fieldwork and community validation in assessment frameworks. The assessment of conceptual understanding and cultural application can be assessed through both practical and context-based tasks in national examinations. Consultations with local communities are essential for cultural sensitivity and authenticity during such reforms.

10. Proposed STEM-IKS Dimensional Barrier Model

Based on the analysis of barriers to IKS integration in STEM education, a barrier Model for IKS-STEM integration has been proposed. The model categorizes the key obstacles into four interrelated dimensions such as pedagogical, epistemological and sociocultural and structural barriers. Each dimension interacts with the others, creating a complex web of challenges that must be addressed holistically for meaningful integration.

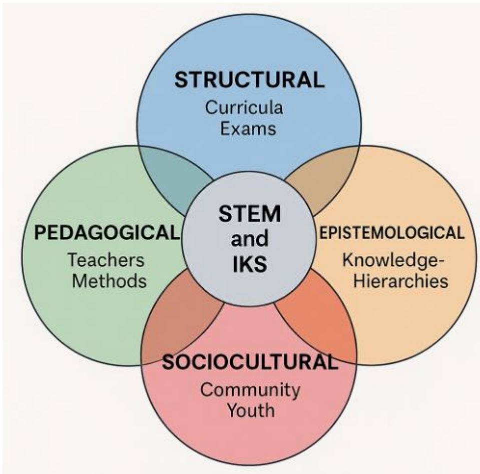

Fig 4.1 STEM-IKS Dimensional Barrier Model

IKS integration into STEM education is a revolutionary process that rethinks who gets to teach, how learning occurs, and what constitutes knowledge. It is not only an act of inclusivity. Although they are important, structural, epistemological, and pedagogical obstacles are not insurmountable. In Zimbabwe and other African contexts, a more pertinent, inclusive, and powerful STEM education system can be established by focused changes in curriculum, teacher preparation, policy, and community cooperation. We create the groundwork for a genuinely Afrocentric and sustainable learning model by recognizing the importance of Indigenous Knowledge Systems and incorporating them into contemporary science education.

Conclusion

The historical, institutional, and epistemological contexts of STEM education present a variety of obstacles to the incorporation of Indigenous Knowledge Systems (IKS). The prevalence of Western epistemologies, a lack of IKS teacher training, a constrained curriculum, and insufficient policy backing are some of the main obstacles. Furthermore, Indigenous knowledge's acceptance in formal education is hampered by cultural beliefs that devalue it. A paradigm shift that encompasses epistemic pluralism, significant policy reforms, inclusive teacher development, and solid community relationships is necessary to overcome these obstacles. For STEM education in Zimbabwe and elsewhere to become more inclusive, relevant, and culturally grounded, these challenges must be addressed.

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Chapter 5: Indigenous Knowledge Artefacts and Conceptual Development in STEM Subjects Instruction in High Schools in Zimbabwe

1 Introduction

In Zimbabwe, Science, Technology, Engineering, and Mathematics (STEM) education is a priority, with the Ministry of Primary and Secondary Education emphasizing Science, Technology, Engineering, the Arts, Heritage Studies, and Mathematics(STEAM).Meaningful learning of Science, Technology, Engineering and Mathematics (STEM) subjects often require students to go through the process of conceptual development (Carin & Sund, 1989). This process of conceptual development can be mediated not only through respective conventional SEMsubjects' laboratory apparatus but also through socio-cultural tools from learners' immediate or indigenous environment (Moorezaid, 2023). However, STEM subject's instruction has remained the same with limited adoption of social and culturally aligned conceptual development tools (Chitera& Moyo, 2021). This Chapter focuses on a conceptual pedagogical model for conceptual development among STEM learners in high schools that incorporates their indigenous artefacts. It presents an IK artefact integrated Conceptual Model for STEM instruction] that can be adopted by STEM teachers for use in their teaching processes. In Zimbabwe, secondary schooling stretches from form 1 to 6. Advanced level just includes forms 5 and 6 and is often referred to as lower 6 and upper 6 respectively. A high school has formed one to six classes. There is a growing realisation that Indigenous Knowledge (IK) is part of the global heritage and natural resource to be utilised in many different ways for the benefit of humanity. This realisation has led to its adoption by educators for use in Science, Technology, Engineering and Mathematics (STEM) subjects' instruction as a conceptual development tool.

Indigenous artefacts and non-indigenous artefacts support different forms of representation in most STEM subjects and have great influence on cognitive and conceptual development in learners. Modern science concepts can only be fully grasped when taught in the context of actual realities, where manipulations, experimentations, observations, descriptions and explanations of spacemen that represents the concept being presented by the teacher are given in contexts that learners can easily refer to or relate to. STEM teaching involves the manipulation, experimentation and observation of spacemen that represent the immediate environment to understand natural event (Omeodu, 2019). The use of IK artefacts enable learners to draw from what they already know to change their existing conceptions resulting in paradigm shift, revolutionization of prior thinking, assimilation, accommodation, grasping, organisation, re-organisation and internalisation of new concepts as they are presented by teachers (Hewson & Hewson, 1983). STEM instruction integrated with IK artefacts facilitate ensures easy crossing of cultural borders into the school (western) science (Ogunniyi, 1988). Jegede (1995) refers to this as collateral learning, which according to Aikenhead, (2002) encourages meaningful learning of STEM.

2. Indigenous knowledge artefacts, conceptual development and STEM pedagogy.

Teaching of STEM subjects is beyond presenting definition of terms rather it deals with presentation of some quantitative measurements and experimental observations that lead to understanding of natural events by learners (Karaca & Akbaba, 2023). When teaching STEM subjects, natural events are described and explained mathematically in the context of daily realities. Theories are stated and sometimes proved (Omeodu, 2019). Teachers also present theories that govern physical nature and numerical expression of these theories.

Over the years, the teaching of STEM subjects has undergone several improvements (Omeodu, 2019). Despite those improvements, students recently have demonstrated poor interest towards learning the subjects due to the teaching methods used by the teacher in the classrooms (Joseph, 2015). Teachers and learners particularly those from indigenous communities are not familiar with the alien meditational instructional tools and strategies that teachers are employing in the classrooms. This is resulting in conceptual development among the learners difficulty.

Generic methods of teaching often fail to link physics concepts properly with learners' prior personal knowledge which they have acquired from their indigenous scientific cosmology for effective conceptual development. Sometimes teachers use inappropriate strategies to incorporate conceptual development tools such as conventional laboratory apparatus and IK artefacts in their instruction. STEM subjects teachers seem to have a limited variety of strategies for adopting IK artefacts for use as development tools during their instruction. They also have limited views about what other teachers say about the use of IK artefacts as conceptual development tools. This resonates well with Moji and Hattingh (2008) who observed that high school teachers have challenges when developing their learners' conceptual understanding, as has been reported across a variety of settings and approaches. Nyaumwe (2004) also reports that some of the instructional strategies teachers used do not facilitate students' conceptual understanding, particularly when teaching STEM subjects. This has caused some challenges in the teaching and learning of STEM subjects inclusive of labelling the subjects as difficult, low pass rates, low enrolments and high dropout rate (Gudyanga, Gudyanga, & Mutemeri, 2013). The result of such pedagogy is that learners end up finding it difficult to access, acquire and develop STEM concepts (Gwekwerere, Mushayikwa, & Manokore, 2013). Conceptual change has to occur for meaningful learning to take place. Teachers have to use different conceptual development strategies during instruction to facilitate effective grasping of scientific knowledge and skills.

3. Conceptual development

Conceptual development describes the progression in the development of understanding of scientific concepts as learners engage in a range of experiences during direct and indirect instruction from their teachers (MacQueen & Guest, 2008). It promotes development of learners' higher-order thinking skills and cognition. It condones rote learning and goes beyond presenting content to help students understand how we know what we know and giving them the tools they need to think and reason in a deeper scientifically acceptable way (MacQueen & Guest, 2008). STEM is an acronym that stands for Science, Technology, Engineering, and Mathematics. It is an educational approach that focuses on integrating these four disciplines. STEM education is not only about teaching individual subjects(Science, Technology, Engineering, and Mathematics), it also focuses on promoting a cross-disciplinary way of critical thinking, problem-solving problem based learning(Tytler, 2020). The goal is to help learners acquire, skills in areas like critical analysis, creativity, problem-solving and increase their interest in STEM-related fields as to succeed in their future careers

STEM subjects are part of school curriculum based on Western culture introduced by colonialists who imposed them and their pedagogy which is not familiar to most indigenous groups of learners (Chitera & Moyo, 2021). Conceptual development instructional strategies and models build bridges between students' prior knowledge and the learning objectives of the subjects.

4. Indigenous Knowledge artefacts and instruction

The significance of IK artefacts in enhancing conceptual development during STEM subjects instruction and contextualising education in general has long been recognized (Webb, 2016). The Zimbabwean school STEM curriculum is dominated by Western values despite the adoption of the Heritage based curriculum enacted in 2025.The Zimbabwe Cultural policy requires teaching of science to be done using IK. The Heritage-Based Curriculum (HBC), also known as Education 5.0, in Zimbabwe aims to integrate the nation's cultural heritage with modern education, focusing on innovation, industrialization, and community engagement. It basically recognized the importance of cultural knowledge in school science teaching. The framework stresses that competences to be taught in science lessons should be informed by cultural knowledge. The STEM subjects' syllabuses require teachers to use familiar and relevant IK based instruction tools.

Indigenous artefacts may be used in teaching of several of school subjects (Webb, 2016). Maddux (1999) asserts that artefacts can be used in the teaching process to enhance conceptual development as they promote communication, contact, and interaction. In the absence of conventional apparatus, IK artefacts provide the core information that students will experience, learn and apply during the course (Driver, 1989). IK artefacts can also be used as tools to facilitate comprehension of ideas in learners, as well as to ensure long-term retention of ideas and topics taught to pupils in a course (Driver, 1989). In some industrialised nations with minority indigenous populations such as Australia, New Zealand, Canada, United States of America (USA), indigenous knowledge has been recognised as a valuable teaching resource (Webb, 2016).

STEM subjects teachers can draw from the indigenous methodologies, knowledge and skills embedded in IK artefacts to foster deeper and richer concept formation and development which could lead to the understanding of new knowledge and skills (Shava, 2005) .The practices with which learners are familiar with in their daily lives which are generally their IK artefacts and habitual indigenous knowledge practices (IKPs) are used to unpack and explain related scientific concepts from the school physics curriculum in the classroom (Mashoko, 2022). The use of IK artefacts in conceptual development among other benefits would widen perspectives of learners through offering alternative explanations and broaden their horizons (Aikenhead & Elliott, 2010). Most learners in high schools in Zimbabwe come from communities with traditional lifestyles where some traditional practices are still being employed. Therefore, learners have experiences connected to their socio-cultural milieu and their local environments. Using their IK artefacts in instruction would also facilitate conceptual development. Besides frustrating the process of conceptual development during instruction, absence of IK artefacts in the conceptual development process causes cultural alienation, symbolic violence, unintentional devaluation of learners' cultural beliefs and values (Tobin & Tippins, 1996) and allows schools to practise cognitive apartheid (Cobern, 1996). The meditational tools teachers are using when teaching are dominated by those from the western culture in the name of conventional physics apparatus which are mainly imported from western countries (Govender & Mudzamiri, 2021).

4 Artefacts and Indigenous Artefacts

Artefacts are simply things or objects that were intentionally created to help achieve some sort of goal (Keil, Greif, & Kerner, 2007). They can be physical (e.g. hand tools or non-physical like poems, stories and social conventions (Keil et al., 2007). Keil et al. (2007) add that pieces of art together with performances are part of intangible artefacts. Therefore, artefacts are both tangible and intangible things created for a purpose of meeting people's needs and wants.

A multitude of meanings are attached to the idea of IK artefacts. The term is complex, contested, ambiguous and elusive. However, in the simplest terms, IK artefacts belong to a class of artefacts or objects that are made by people belonging to a particular place especially of cultural nature and have specific meaning in these communities. Onwu and Mosimege (2004) argue that IK systems (IKS) generally include all forms of knowledge, technologies, know-how, skills, practices, values, norms, beliefs, teaching and learning approaches, art, dances, songs, etc. that enable the community to achieve stable livelihoods in their environment. IKS is dynamic, hence, it incorporates new elements and concepts as contacts with other people and new phenomena are established. Therefore, IKS are those forms of knowledge that the people of the formerly colonised countries survived on before the advent of colonialism was swept aside and denigrated by the colonialists such that the science associated with the IKS was labelled as empirical and superstitious (Mapara, 2009). IK artefacts reflect the wisdom of people who have lived a long time in a place and have a great deal of knowledge about their environment. IKS comes in the form of values (Aikenhead, 2001), technology (Moji & Hattingh, 2008) , games(Moji & Hattingh, 2008), language (Barnhardt & Kawagley, 2005), knowledge of the environment in general (Kawagley, Norris-Tull, & Norris-Tull, 1998), and plants and animals in particular (Keane, 2006).

In Zimbabwe some tangible IK artefacts are made from local materials that may include wood, leather, cane, fibre, bamboo, animal horn and other durable materials. Examples of tangible IK artefacts include traditional drum, reed mats, winnowing baskets and hoes. Intangible indigenous artefacts may include traditional performances, stories and games like rakaraka, pada and chuti.

5. IK Artefacts and their suitability for use as conceptual development tools in STEM subjects' instruction

The possibility of using IK artefacts in teaching and learning of STEM subjects in High schools rests on the fact that, there are features of IK artefacts that are common across different ethnic groups in indigenous communities with just slight variations that dependent upon natural environments and social histories. There are also similarities between IK artefacts and Western artefacts, some of which are used as conventional instructional tools in the teaching of STEM subjects in schools. Some indigenous societies have IK artefacts with features that resemble formal STEM subjects' concepts (Sithole, 2016). Sithole (2016) argues that indigenous Science is similar to classroom STEM subjects concepts, although it lacks the conventional mathematical rigours needed in its formal illustrations that include abstraction and formulaic approaches. Some indigenous artefacts and technology have been developed using formal physics related skills (Shizha, 2014). There is evidence that some of the

IK artefacts were made through application of sound STEM based scientific principles which were empirically derived through systematic observation and experimentation, though not necessarily explained using conventional STEM based scientific terms (Baquete, Grayson, & Mutimucuio, 2016).

History shows that even in Zimbabwe IK artefacts have been in use as a pedagogical resource since time immemorial (Govender & Mudzamiri, 2021). In North America, efforts to improve the understanding of STEM subjects by learners through their own cultural ancestry knowledge were noted in Alaska (Kawagley, Norris-Tull, & Norris-Tull, 1998). Similar efforts have been made in primitive societies in Zimbabwe, where people could use the knowledge they had already acquired to pass on new information or ideas to their fellows (Govender & Mudzamiri, 2021). The use of songs, stories, art works, participant observations, experiential learning, modelling, meditation, prayer, ceremonies-rain making and learning through authentic experiences and individualised instruction, and learning through enjoyment were popular teaching strategies (Mapara, 2009).

Local artefacts were used as examples, in analogies and as instructional aids in demonstration of skills and ideas (Govender & Mudzamiri, 2021). The use of IK artefacts in instruction was effective, meaningful, and relevant since these indigenous societies were self-sustaining in their needs (Govender & Mudzamiri, 2021). Therefore when the IK artefacts are used in instruction they are not mere ‘attention-seekers' but are an embodiment of physics concepts' meanings. Their emotional impact on physics learners is far-reaching and positively affects the attitudes of learners towards the subject.

6. Post-colonial theory, Social constructivism and the use of IK artefacts for conceptual development in STEM instruction

The use of IK artefacts for conceptual development is hinged on Post-colonial and Social constructivism theoretical frameworks which are guided by Vygotsky’s ideas. Educators use theories to build curricula, select materials for instruction, choose instructional procedures and strategies among other uses. Post-colonial and Social constructivism are characterised by a set of principles relating to how knowledge is created and how individuals develop understanding. Constructivists view learning as an active process of constructing rather than acquiring knowledge. Therefore, instruction is viewed as a process of supporting the construction rather than communication of knowledge (Duffy, Lowyck, Jonassen, & Welsh, 1993).

Vygotsky finds a significant role of what he called “tools” to facilitate conceptual development in learners. Tools are artefacts created by humans under specific cultural and historic conditions (Vygotsky, 1962). (Vygotsky, 1962) argues that humans do not interact directly with the physical world without the intermediation of tools. These tools can be used as aids in solving problems that cannot be solved in the same way in their absence, like facilitating conceptual development. This shows that the tools can also be used in instructional scaffolding to make learners understand concepts in advanced level physics. Margolis (2020) views scaffolding as a technique for helping the students in their Zone of Proximal Development (ZPD) in which the adult provides hints and prompts at different levels. Raymond (2000) posits that knowledge systems like IKS and its associated artefacts can be part of the scaffolds or tools in the teaching and learning discourse. Mishra (2013) supports that, the tools may also include resources used in classroom demonstrations, similes or given as examples in lessons. They also include artefacts which can also be used as apparatus in experiments. Therefore, teachers can consider local culture, indigenous artefacts, and local ways of knowledge as well as community knowledge as intellectual tools of adaptation that can move learners into their ZPD.

These tools may also be employed by STEM teachers to facilitate mediated action and internalisation, as well as appropriation of concepts by learners as they interact in the ZPD and also during their transition into the unfamiliar zone. The mediated actions in the ZPD enable teachers to make learners understand STEM concepts easily through interactions with their indigenous culture and its associated artefacts. Lave and Wengner (1991) maintain that learning is best achieved when learning tasks are encountered, practised and applied in real world contexts, especially the socio-cultural settings.

Post-colonial theory emphasises the power of the IK as a way for competitive scientific advantage (Mapara, 2009). The theory challenges the formerly colonised to reclaim their lost intellectual, pedagogical, social, political, economic, and linguistic cultural practices to establish their new form of knowledge base and pedagogical practices. Hence, the post-colonial theory allows the indigenes to assert their presence and identity through reclamation of their past which colonialist had done everything to dismantle. Everything that linked to the indigenes was viewed as backward, thus the theory challenges the indigenes to speak for themselves, in their own voices, for a return to some of their cultural knowledge and practices like the use of IK and its associated artefacts in pedagogy.

7. Strategies for using IK Artefacts as conceptual development facilitation tools when teaching and learning STEM subjects

There is a repertoire of strategies to facilitate students' conceptual development through the use of IK artefacts in STEM education. The choice of the conceptual development strategies and the ways they can be implemented in the teaching processes depend on what teachers would want to achieve and the nature of the learners. These strategies are given in form of a conceptual model which is summarised in Fig 1. Pedagogical models help people to understand relationships between learning, how it happens, and how it can be facilitated, and so they direct one towards a coherent plan to bring about certain types of learning and to achieve the curriculum goals. Figure 1 provides a visual representation of how the conceptual model is a structured. The figure shows the key concepts, variables, and relationships among IK artefacts, STEM subjects' instruction, and the strategies that can be involved to link them. It serves as a framework for understanding some of the available conceptual development strategies and how they can be used as well as their effect on instruction. The model also provides guidance to teachers on conceptual development process during their teaching.

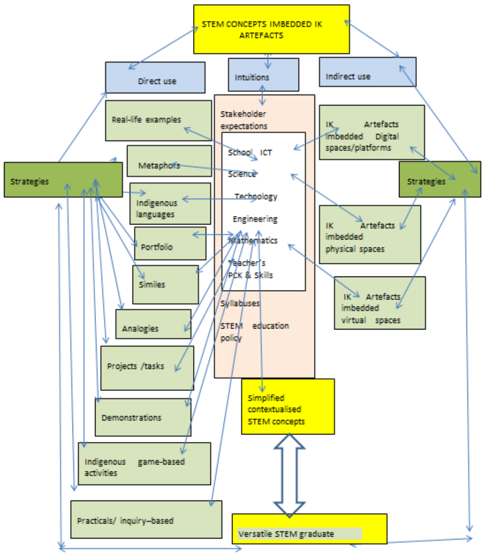

Figure 5. 1: The IK artefacts integrated Concept Development Model

The model provides a picture of how teachers can use IK artefacts to facilitate conceptual development in their learners when teaching STEM subjects. The model requires that learners and teachers have knowledge about the IK Artefacts to be used as indicated in figure 1. The model indicates that IK artefacts can be used directly and indirectly in the conceptual development process. The direct use include involves the use of real IK artefacts or their models physically during classroom instruction and out of classroom instruction. The strategies associated with the direct use of the IK artifacts are indicated in Figure 1 and they include: use of real-life examples in lesson presentations; indigenous game-based activities; indigenous languages; projects and tasks; demonstrations; practicals and inquiry–based approaches; portfolios; analogies; metaphors; similes. Strategies associated with indirect use of IK artefacts include creating space for the IK artefacts in the learning environments. This environment empowers learners to succeed in understanding and survive as competent lifelong STEM learners. The Model suggests that this could be done through establishing IK artefacts imbedded virtual spaces IK artefacts imbedded Digital platforms and IK artefacts imbedded physical platforms as shown in figure 1. The Model caters for different learners inclusive of embodied and non-embodied learners, Digital and non-digital learners and those who want to use Artificial intelligence (AI). Leaners with different learning styles are also considered inclusive of kinaesthetic, visual, auditory, tactual olfactory and cerebral learners. This is because different STEM learners use each of the learning to different. The model also allows the use of different teaching and assessment methods.

The arrows indicate the nature of the interaction. Some arrows are pointing in the opposite direction to indicate the need for feedback in every interaction or process. Feedback allows not only the monitoring and evaluation of the effectiveness of the conceptual development strategies but of the whole learning process.It also allows accommodation of knew strategies and newly generated perspectives in the learning of STEM subjects. The model indicates that both direct and indirect use strategies can influence the conceptual simultaneously as indicated by their respective arrows that are converging at the center which represents the classroom and the school surroundings as indicated in figure 1. In these learning spaces the teachers using their pedagogical skills integrate the strategies imbedded with IK artefacts with the conventional western based instruction strategies that are already dominating the learning spaces to clarify, simplify and contextualise the concepts thereby facilitating easy conceptual development among learners. The issues of relevance and quality are guaranteed by ensuring that everything that enters the learning space has to pass through a screening process which is guided by quality control documents such as the STEM education policy, syllabuses, school policies, stakeholder expectations. The screening process continues even during the instruction process.

The arrows connecting the IK artefacts and the learning spaces which are labelled intuitions represents dynamics which are non-linear , emergent and do not follow the rules of logic and deployment of practical or experimental reasoning inclusive of intuitive teaching involving IK artefacts. This is because in some situations activities in the teaching process cannot be executed linearly; stages are not sequential and standardized and cannot be sequentially and serially carried out. Ogunniyi (1986) revealed that in some situations scientists (STEM educators) do not follow the rules of logic and deploy practical or experimental reasoning, intuition and sometimes serendipity. The teacher connects learners and IK Artefacts in instruction meaningfully, productively, effectively without the use of clearly articulable, explicit pre-planned teaching or learning strategy for his learners. Generally the teaching would be subjective and through embodied experiences of the teacher which depends on the time he spent in the environment, environment encountered and the effects felt. However these also have to pass through the screen process as indicated by the arrows passing through to the classroom [Figure 1].These dynamics are non-linear and emergent and fit well with what actually happens practically with a good teacher in the real teaching process.

After this process the model indicates that the graduates would be versatile as they would be having understanding of the STEM concepts from the western angle and their own indigenous context as well as both IK artefacts and conventional STEM apparatus or artefacts as indicated by the arrows pointing at the graduate [see fig 1]. The learners would also gain a deeper understanding of their IK artefacts as indicated by the arrows from the top to the graduates on the model [see fig 1]. A deeper understanding of IK artefacts and acquisition of cultural competences would lead to their improvement and effective solving of problems in communities as IK artefacts are designed to solve problems. A school then becomes a social institution whose broad concerns and issues are to be addressed by its curricula. The Model allows students to acquire life-long learning skills which are necessary in our ever-changing environments.

8.1 The details of the strategies indicated in the model

8.2 The use of context-bound and concrete examples of IK artefacts

The use of context-bound and concrete examples of IK artefacts in lesson presentations is indicated as one of the strategies that teachers can adopt to facilitate conceptual development when teaching STEM subjects. This involves the of use context-bound and concrete examples of IK artefacts as a way of facilitating conceptual development. Teachers may explain a STEM concept by first casting it in indigenous terms to which the learners relate. The teacher may start by explaining the indigenous way of understanding the concept, by looking at the IK artefacts. After learners have understood the concepts presented in the indigenous way, it can then be explained in western terms to show how the conventional physics complement their traditional understanding and vice versa. Acquisition of new knowledge is heavily influenced by pre-existing knowledge (Carin & Sund, 1989).

When teaching, the teacher may also employ a technique of starting by isolation of STEM concepts perceived in the artefacts in his process of imparting and elaborating some STEM concepts. He or she may resort to using parts or the whole artefact to bring out meaning or simplify concepts. This may stimulate learners to learn STEM concepts in a smart and enjoyable way and also to construct school STEM subject's content and pedagogy from their own experiential ideas. This process would promote STEM subjects contents learning where learners would have to construct and modify knowledge from parts of artefacts and code it in their mental schemes to allow deeper understanding of the concepts.

Teachers would then use various resources available in their local context to support students' conceptual development and understanding. By relating what was taught in the class with what is associated with IK artefacts, students would be engaged meaningfully in STEM concepts discussions and are able to mediate their understanding of concepts from their experiences to STEM subjects content in the classroom (Driver, Asoko, Leach, Hortimer, & Scott, 1999) and thus acquired conceptual understanding. The benefits of the inclusion of cultural examples in Science pedagogy is that it provides both teachers and learners with opportunities to explore conflicts between STEM based and cultural ways of understanding natural phenomena. This exploration may enhance conceptual development on the part of learners, while on the part of teachers it might help them to improve their teaching strategies as well as the design of teaching and learning materials.

8.3. Indigenous Game-based Physics Activities

The use of Indigenous Game-based Physics Activities is also indicated in the model as a strategy that facilitates conceptual development in learners. Indigenous games involving or based on STEM based activities are an important resource that can facilitate learning in schools, as was also noted by Ngulube (2015) .Nyota and Mapara (2008) note that Indigenous games are resources which are part of IK artefacts which are unique to any community or culture. There is evidence of the usefulness of indigenous games in conceptual development (Ezeanya-Esiobu, 2019). Indigenous games involving or based on physics activities are essential in indigenous learner's education and can be used successfully to develop some skills and knowledge during teaching and learning(Ezeanya-Esiobu, 2019) Indigenous games cultivate knowledge, positive attitude towards the subject and gives learners opportunity to practise skills (Oguamanam, 2006).

There is dominance of Western versions of games in schools some of which are physical where learners may engage in play or manufactured and digitised by industry (Jackson & Sorensen, 2003). Indigenous games are active, experiential, contextualised, social, intrinsically motivated, and problem-based, and they create positive emotions such as curiosity, joy, optimism, and decision-making which generally agreed with (Foucault, 1969).

Generally the Context-culture-based framework involved in the games dictate how the traditional games blend with STEM concepts formation to motivate conditions and conceptual ecology for conceptual change to occur. The activities conducted during the game by the participants in each session directed their explicit learning of embedded STEM concepts and may significantly change the students' conception.

8.4. Indigenous Languages

The use of native languages and indigenous terms as other strategies IK artefacts can be used to facilitate conceptual development in learners. Indigenous or home language and indigenous terms may be maintained and then used as a basis for learning the language and terms that count as scientific. In this case, learning is considered as a social process in which language plays an important role as indicated in the social cultural theory.

The issue of both teachers and their learners having insufficient proficiency in English to be able to use it in STEM subjects' content instruction was also noted by Mkimbili (2019). This emerged when he was studying Meaningful Science Learning by the Use of an Additional Language based on a Tanzanian Perspective in 2018. Code switching (the use of more than one language in discourse), transliteration, and classroom talk by learners should be allowed to ensure effective communication of ideas. Gumbi (2017) notes that there is empirical evidence that code switching is important during instruction as it deals with the language gap in physics classrooms. Code switching allows learners to think, to argue, and to classify their thoughts. This would allow learners to ask questions in their own language for better understanding of the concepts and unlock their brains into understanding complex concepts (Gumbi, 2017). The teacher will serve as the translator from the indigenous language and codes to the scientific language to make the language spoken in class both comprehensive and engaging.

The advantages of using indigenous language cited by teachers generally agree with those cited in literature. Scholars like Cronje, de Beer, and Ankiewicz (2015) observed that learners taught in their home language perform significantly better than those taught in English. Cronje et al. (2015) argue that the use of indigenous language allows learners to assimilate information faster than when the language of learning and teaching is foreign. Terminology of the local language cannot encompass all the concepts in science (Dziva, Mpofu, & Kusure, 2011a).

Generally teachers should allow learners to use the discourse spoken in indigenous science settings such as scientific vocabulary, words, and actions used to describe scientific processes, for example, observing, inference, experimentation, or discourse techniques normally reserved for STEM subjects like argumentation as useful tools to facilitate conceptual understanding. The teachers should find ways of scaffolding the indigenous language of the learners to meet in its unique ways the language requirements in the STEM community in order to close the gap between IK science ideas and the classroom STEM subjects content. The teachers, teaching in the mother tongue which is part of IK, enables better understanding of STEM subjects concepts (Dziva et al., 2011).

In situations where indigenous learners do not have the necessary subject terminology, which made it difficult for them to transfer conceptual understanding from mother tongue to English, teachers should be allowed to work with the learners and knowledgeable people in their communities and the elderly to create convenient or working vocabulary in their respective community languages to name or describe concepts or scientific processes, laws and theories. They can sometimes borrow the European vocabulary and merely modify its pronunciation so that it sounds like some convenient indigenous terms. Teachers can also give meaning to accessible words that are explanatory of the concepts, rather than borrowing from Western languages by phonetic transcription. There would be development of a mother tongue nomenclature for STEM education with some IK and IK artefacts connotations. This will necessitate the development of modern scientific vocabulary in the various African indigenous languages.

8.5 Projects and tasks

The adoption of IK artefacts embedded Project and IK artefacts task based instruction is also among the strategies that teachers can adapt to facilitate conceptual development in their learners. Projects and tasks involving making, using, evaluation, and improvement of IK artefacts that are related to STEM concepts targeted by instruction should be assigned to learners. Tasks are activities that are purposefully designed or selected to focus the learners' attention on some science concepts and/or process. Tasks that require scientific thinking and exploit the pedagogical affordance associated with IK artefacts should be encouraged in schools. Tasks would initiate scientifically fruitful activities that lead to a transformation in what learners are sensitised to notice and competent to carry out.

The teachers should encourage learners to produce and use IK based learning artefacts as part of their projects and learning tasks. In the processes of carrying out the tasks, students may divulge much of what they know about the STEM concepts and interrelationships among these concepts as they plan and manipulate the artefacts (Carin & Sund, 1989). The other strategies may be to ask learners to look at IK artefacts that have equivalent functions to some western artefacts covered during classroom instruction as part of their projects and tasks. The other project approach may involve a situation where learners are assigned or choose a topic from a STEM subject associated with IK artefacts for in-depth study, particularly on the concepts taught or to be taught in class. The learners produce a report that can be assessed or presented to the class or panel of examiners by the learner. This promotes independent learning and individualised teaching that allows self-correction, creativity and improved conceptual understanding. Projects and tasks provide ample opportunities for learners to utilise objects from their socio-cultural environments while gaining practical experience of the content of STEM subjects in a meaningful way (Makie, 2019). Projects and tasks would promote consolidation, practice, application of learnt concepts and skills, allowing modification of the students' beliefs as well as accomplishment of a conceptual change.

8.6. Demonstration

The model also indicates the use of both teacher and student demonstrations as ways of facilitating conceptual development among learners. Learners may be given tasks and skills to imitate or demonstrate a certain STEM concept or process, using IK artefacts as a way of showing and contextualising the desirable scientific explanations targeted by instruction. These student demonstrations can also be effective ways of checking whether learners have acquired the intended concepts and skills. In demonstrations, students can divulge much of what they know about the STEM concepts and interrelationships among these concepts using conventional STEM equipment (Carin & Sund, 1989). Kestin and Miller (2022) note that online and live demonstrations togetherwith interactive lecture demonstrations respectively using different tools are strategies for exploring and enhancing conceptual development.

8.7. Practicals and inquiry – based tasks.

Practicals and inquiry based activities involving the use of IK artefacts are other strategies that can be adopted to facilitate conceptual development when teaching

STEM subjects. Practical work is any science teaching activity in which students, working individually or in small groups, observes and/or manipulate objects or material they are studying (Millar, 2010). The teachers claim that their learners easily understand science concepts with an additional language when they participate in hands-on activities and study science by observing it.

These observations indicate that when the teacher uses inquiry-oriented activities, students are better engaged with STEM talking and thinking. Mkimbili (2019) notes that students' engagement with physical artefacts can make them understand the subject more easily than learning a subject only theoretically and when an additional language is involved.

Constructivist theory of learning affirms that learners like to touch things, to handle, prod, feel, and fondle objects for them to understand them. Handling an artefact allows learners to use their senses, develop questioning and problem-solving skills, strengthen their understanding of a period, and empathise with people from the past.

During practicals, learners demonstrate science process skills and knowledge they would have acquired, in a practical activity that is hands-on. In this activity, learners are provided with laboratory equipment and requested to use the equipment to solve a posed problem. Traditionally, practical work in science education involves learners following a highly structured, step-by-step approach, where teachers dominate and control the sequence of activities, while learners play a passive role (Zion & Sadeh, 2007). The step-by-step procedure is laid down by the teacher or the recommended textbooks. When these are adopted, learners are expected to use context-sensitive strategies, critically analyse the results, and link with their indigenous home experiences, IK, and IK artefacts. Tasks involved in practical activities should present to learners new situations associated with the target concepts or concept to be learnt so that development of the concept would not be based on factual and procedural recall which would affect their retention, subsequent development and internalisation. Mkimbili (2019) notes that students talk more in practical sessions, but are less engaged with science talk when they are in direct instruction sessions. Mkimbili (2019) also observed that both teachers and students use gestures, home language and materials at hand to ensure understanding during the practical task.

8.9. Portfolios

The use of portfolios inclusive of IK artefacts is also included in the model as another strategy that can be adopted to facilitate conceptual development when teaching STEM concepts to learners. This resonates well with Carin and Sund (1989) who note that portfolios have gained popularity as effective tools in scientific knowledge and concepts creation. A portfolio is a systematic collection of selected learners' work (Popham, 2002). Portfolios contain consciously selected examples of learners' work that are intended to show the learner's growth toward important learning goals or progression towards understanding a certain concept. Folios or portfolios are records of classified aids, articles, research papers, presentation papers or various hand-outs about IK artefacts related to a particular concept. They also included samples of real IK artefacts or their models. In this case concepts' details are conveyed and understood easier upon touching, seeing and direct access including close inspection of the artefacts in which target western STEM concepts are embedded. The learners' work in the portfolios is presumably a reflection of the learners' level of abilities or level of understanding over a wider range of instances and concepts. Therefore, portfolios would allow teachers and even learners themselves to check on their level of understanding of a STEM subject concept.

Egunza (2014) argues that these are important because no one has a photographic memory to remember everything about the previous part of the concept that the learner has been struggling to understand. The respective IK artefact in the portfolio would remind the learner and allow cumulative conceptual development amongst the learners.

8.10. Metaphors and Similes

Metaphors and Similes that involve the use of IK artefacts can be adopted to facilitate development of abstract phenomena and concepts amongst learners during instruction. A set of known concrete and familiar ideas help students understand difficult and abstract concepts presented during classroom instruction. Metaphor is a mapping between two conceptual domains which provides a powerful tool to understand one domain of knowledge in terms of another (Amin, 2009). The conceptual metaphors help to deal with relatively unfamiliar and abstract domains of experience in a familiar and tangible way (Amin, 2009). It can be taken as a mapping in which the abstract ideas map into concrete, strong and meaningful images that are developed in different social and cultural contexts for a different purpose.

There are two parts of a conceptual metaphor: target domain and source domain. Basically, metaphor is a mapping between the source domain and the target domain. The source domain is familiar, concrete and based on everyday activities and experiences of learners, whereas the target domain is an unknown, abstract and difficult set of ideas (Amin, 2009).

8.11. Analogical representations and reasoning

Analogical representations and reasoning involving IK artefacts is another strategy that can be adopted to facilitate conceptual development when teaching STEM subjects. Familiar IK artefacts blended with analogies are potential learning resources in improving sense-making of new STEM concepts during instruction. Analogical representations are inferentially rich; hence they promote development of cognition of STEM concepts based on the familiar experiences and contexts. In this regard, teachers should regularly refer to some IK artefacts or their characteristics in their lesson presentations in conjunction with appropriate analogies in class. In some situations, pointing out analogies, metaphors, songs, poetry, and relationships with IK and IK artefacts connotations as a way of bringing IK, IK artefacts and associated indigenous pedagogical techniques in STEM teaching.

Leach and Scott (2003) see analogies as simplified models established on familiar concepts and intended to elucidate abstract concepts. Analogical representations stand in for what they represent by virtue of similarities. Teachers can use well-thought-out and well-prepared teaching repertoire of analogies in which they use contexts that would enable learners to understand concepts and even to construct their own knowledge rather than being passive recipients of knowledge from the teacher. This strategy is supported by many science educators (Treagust, Harrison, & Venville, 1998).

8.12. Indirect use of IK artefacts in conceptual development

IK artefacts can be indirectly involved to facilitate conceptual development in STEM subject's teaching and learning processes. These strategies allow sustained and prolonged exposure of STEM students to relevant IK artefacts-integrated learning environmental designs. The strategies include creating indigenous spaces in both the virtual and physical learning environments as some of the ways of achieving that sustained and prolonged exposure that would inevitably lead to conceptual development. Furthermore, these supportive environments may eventually lead to development of sophisticated epistemic belief systems, consequently providing better teaching and learning frameworks as was also noted by Morales-Doyle (2018). Driver (1983) notes that the alternative conceptions that learners have constructed to interpret their experiences have been developed over an extended period of time; one or two classroom activities with limited time are not going to change those ideas.

Teachers should develop locally developed and owned indigenous pedagogical innovations and initiatives that would ensure the creation of IK artefacts spaces in the STEM learning environment as a way of achieving sustained and prolonged exposure. Learners are given enough time to identify incorrect information, revise, and replace it. This is called the "Conceptual Change Process" (Smith, Blakeslee, & Anderson, 1993). This makes conceptual development among the learners less of a rule-bound routine and more of engaging real life activity. The creation of IK space allows sustained and prolonged exposure to STEM concepts presented in familiar objects and contexts, together with the usual conventional STEM apparatus. This environment encourages them to confront their own preconceptions and those of their classmates, and then work toward resolution and conceptual change. This generally allows conceptual development through extended observation and embodied explorations. Extended observation allows more time for STEM processes of identifying properties, discovering relationships and searching for answers (Sithole, 2016).

Embodied explorations in physical learning environments are associated with spontaneous embodied explorations (Wilson, 2002) and intuitive reactions (Guest & MacQueen, 2008) that support causal learning. Spontaneous embodied explorations are explorations which are not explicit, conscious, mentally representative, or articulate. They basically involve the body or done through the body. These explorations are basically informed by aspects of the body, such as senses when the body is interacting with the physical environment (Wilson, 2002). The physical and psychological elements in the environment evokes or stimulate embodied knowledge of the learners as they enter the learning environment and begin to make sense of the physics concepts associated with the elements in the environment. However, in Embodied and intuitive explorations there is little guidance on how to navigate higher-order constraints on scientific induction, such as the control of variables or the coordination of theory and data.

9. Challenges on conceptual development using IK artefacts

The challenges that may be encountered when IK artefacts are used in the conceptual development during instruction include the fact that current teacher training curricula offered in teachers training institutions do not include the idea of integrating IK artefacts in the teaching of STEM subjects. This means graduate teachers from these institutions are not aware of how they can use IK artefacts at their disposal for conceptual development in instruction.

Teachers may also be under tremendous pressure to teach for examinations which do not include questions which relate to the use of IK artefacts. The other challenge isthat teachers will not be able to cover the syllabus because use of IK artefacts requires extra time since the teachers are also required to use conventional artefacts which are required by the examiners. There are also limited relevant instructional materials that incorporate cultural knowledge in the schools' STEM subjects' laboratories. In addition to these hindrances is the fact that learners under the same teacher have different cultural backgrounds hence may have different IK artefacts which poses a dilemma on whose IK artefacts to use in the concept development process. Modalities for implementation in schools for countries with a diverse culture like Zimbabwe can be a difficult task. There are many ethnic groups in Zimbabwe. These include: the Shona, Ndebele, Tonga, Nambiya, Kalanga, Venda, and the Shangani.

Ausubel, Novak, and Hanesian (1968) pointed out that preconceptions are amazingly tenacious and resilient to extinction. Student preconceptions are so strong that, in some cases, they are preserved in the face of obvious and contradictory evidence (Arthurs, Elwonger, & Kowalski, 2021). This is also a challenge which threatens the effectiveness of the strategies for conceptual development.

Conclusion

The Model indicates that the use of real-life examples in lesson presentations; indigenous game-based activities; indigenous languages; projects and tasks; demonstrations; practicals and inquiry–based approaches; portfolios; analogies; metaphors; similes and creating space for the IK artefacts in the learning environments are some of the strategies that teachers can adopt when using IK artefacts for conceptual development in physics instruction

It is imperative to have special workshops, symposia, seminars, conferences where teachers are shown on how IK artefacts can be incorporated into physics instruction to enhance learners' conceptual development and understanding. More research is needed on how these strategies can be utilised using the integrationist approach for more effective conceptual development using the IK artefacts

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