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Developing a Theory for Conceptualizing Ancestral Life Sciences (Traditional Teachings of Life)

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Abstract. This paper presents the Theory for Ancestral Life Sciences (TALSc.) as it introduces an Indigenous Knowledge integrated curriculum intended for Life Sciences teachers' training and teaching practicum. This framework was developed in response to the observed cultural wisdom disconnect from traditional approaches of Life Sciences teaching. The TALSc. model challenges this fragmentation by proposing a holistic approach to Life sciences teaching, which integrates ancestral wisdom with scientific pedagogical approach. The framework maintains scientific content within the Life Sciences CAPS curriculum requirements while maintaining cultural familiarity. The framework advocates that a better comprehension of Life Sciences concepts is rooted in our spirituality, indigenous wisdom and lived experiences of our ancestors. TALSc. model emerged as an educational theory that positions ancestral wisdom as a centre of understanding Life Sciences content. It was developed using a Theoretical research approach that entails the process of building theoretical structures to make sense of phenomena, usually without requiring empirical confirmation. Its focus is on initiating theoretical frameworks or updating ones that currently exist to offer the necessary theoretical basis. The TALSc. model decolonizes Life sciences content while restoring Indigenous Knowledge Systems to contemporary science educational settings. It promotes cultural relevance to Life sciences content and inculcates respect and appreciation of heritage in both learners and teachers. Lastly, it serves as pedagogical guide in community engagement, IK integration in Life sciences curriculum and transfer of indigenous knowledge from one generation to the next.

1. INTRODUCTION

The existing Scientific educational programs tend to sever subject matter from its connections to cultural heritage as well as spiritual and historical frameworks (Felgueiras et al., 2022). The proposed TALSc. challenges a traditional approach by equipping pre- and in-service teachers with a technique that advocates for the interconnection of the Life Sciences content to ancestral science. This brings in an ancestral knowledge strategy to break the fragmented traditional approach. Studying Life Sciences education should centre around the teaching practices that employs Indigenous Knowledge (IK) integrated methods suited for modern education applications. TALSc. redefines contemporary Life sciences which seeks to bring resistance to traditional science methods. This theory upholds that true learning and a correct natural understanding demands respecting sacred bonds that integrate soil, living beings, ancestral connections and communal attachments.

2. LITERATURE REVIEW

2.1. Traditional Methods of Acquiring Knowledge

There is a vast number of traditional methods of inquiring knowledge including scientific inquiry which entails seven steps. For instance, in scientific inquiry, a learner identifies a problem, check literature and gather information from articles on what is already known about the identified problem (Yeoh et.al., 2024). This provides a learner with insights on what is already known about the problem. You then propose a learned guess (hypothesis) to be tested. Under controlled conditions, a learner design an experiment to test predictions. Collect and analyse data using quantitative (statistics) or qualitative (checking themes and patterns) methods. Draw conclusion if the findings uphold or refute the hypothesis. Disseminate findings through publications or presentations. Based on results, a researcher may fine tune, adjust experimenting conditions and repeat it.

Another form of transmitting information is the transfer of knowledge in various forms (oral history) verbally which is developed among the indigenous and ancestors' cultures, in the form of narrated stories of the warriors, myths (intsumo) that comes with life lessons, and lived experiences of indigenous communities like how hunting was done (Sommer & Quinlan, 2024 and Marino, 2024). Knowledge can also be acquired through observations, that is, learning through observing indigenous communities' behaviours, actions, and learning how things are done in an informal manner. Sometimes knowledge can be acquired through scaffolding, under the guidance of someone who is more experienced than you. For instance, if a learner is struggling to understand the Life science content, a teacher may come in as a more knowledgeable other (Lin & Puntambekar, 2024). There is another form of learning called learning by doing, in which learning is acquired by immersion into indigenous communities through participatory research (Nganga & Kambutu, 2024) and reflecting upon the outcomes of the experience itself. Analysing traditions and norms on what is learned during day-to-day activities.

3. THEORETICAL FRAMEWORK

In response to a need for decolonization of science education, there is a significant shift, that we conceptualize and therefore theorize an innovative and transformative mode of teaching and learning, known as the Theory of Ancestral Life Sciences

(TALSc.). The framework aims to position cultural wisdom as the centre of Life sciences teaching and learning.

TALSc. challenges Eurocentric frameworks that have sought to dominate scientific thought processes in science education. On the contrary, it promotes the holistic perception of life where the biological phenomena cannot be separated from the spiritual one (Williams, 2024). Life Sciences is not a subject that can be studied independently, but a living entity that interacts with natural environment, humanity and ancestry. This theory precipitates learners in a system of a relationship embracing ancestral knowledge and power through an inquiry-based community. When viewed through the TALSc. lens, Life Sciences is not simply a subject in the CAPS curriculum, it is a vehicle for change in content delivery, for developing relational learning, for documenting and preserving IK. This way, TALSc. plays a huge role in the demarginalization of the African people and for the honour, value and reciprocity in education system.

The subsequent models offer frameworks for understanding and implementation of IK integrated methods in formal educational settings. The *Indigenous Knowledge Systems (IKS) Framework, Ubuntu Pedagogical Model and Two-Eyed Seeing (Etuaptmumk) Model* align closely with the Theory of Ancestral Life Sciences (TALSc.) framework, both philosophically and pedagogically.

3.1. Indigenous Knowledge Systems (IKS) Framework

The Indigenous Knowledge Systems (IKS) Framework was established in South Africa as a policy framework to recognize and structure indigenous forms of knowing. It emphasizes the importance of preserving static knowledge and intellectual property and incorporating IKS into national development strategies. The framework is relevant to TALSc., as it supports indigenous knowledge as relational, changing, and embedded in the community. However, it lacks guidelines for teachers on how to integrate IKS into formal education, such as Life Sciences curriculum content. The link between IKS pedagogies and conventional assessment methods is also poor.

3.2. Ubuntu Pedagogical Model

TALSc. is a model that incorporates the Ubuntu Pedagogical Model, a framework that promotes relational learning, ethical, and community-centered education based on African humanism (Freire, de Sousa Santos, Tamale, Praeg, Chitando, Magadla, & Makua, 2024). Ubuntu emphasizes human dignity, compassion, and social harmony in life sciences learning. The model emphasizes mutual relationships between learners, educators, and communities, and emphasizes cultural identity, respect of elders, and ecological responsibility. However, it faces challenges in integrating relational and ethical education into formal assessment and policy frameworks, as well as aligning with standardized assessment models and traditional educational policy structures.

3.3. The Two-Eyed Seeing (Etuaptmumk) Model

The Two-Eyed Seeing (Etuaptmumk) model, developed by Mi'kmaq Elder Albert Marshall, promotes the synthesis of Indigenous and Western scientific approaches. It balances spiritual and empirical perspectives, promotes co-learning, and encourages critical involvement of learners in both knowledge systems (Tremblay & Martin, 2023). The Two-Eyed Seeing and TALSc. models share the commitment to scientific and indigenous perspectives, and the TALSc. model welcomes learners to explore biology, ecology, and health using scientific and ancestral/spiritual interpretations. However, there are several challenges in integrating the Two-Eyed Seeing Model into modern educational settings. Systemic institutional resistance, disagreement on suitable strategies, lack of contact with Indigenous knowledge holders, and mismatch between Western standards of Life sciences assessing and credentialing and Indigenous ways of assessing and validating content learning are some of the challenges. Additionally, inadequate focus on ecological and spiritual knowledge in academic curricula is another weakness. To address these discrepancies, higher academic institutions and indigenous communities should take intelligent actions, enabling culturally responsive approaches to teaching, developing mutual respect, and creating realistic approaches that respect both knowledge systems on equal grounds without discrimination.

4. METHODOLOGY

4.1. Theoretical Research Design

This study utilizes Theoretical Research design, which involves building theoretical structures or conceptual frameworks to understand phenomena without immediate empirical confirmation. It aims to resolve abstract questions and provide a theoretical basis. The research is conducted in philosophy, mathematics, life sciences, theoretical physics, and education, focusing on how integrated learning can motivate life sciences learners (Lynch, Ramjan, Glew & Salamonson, 2024).

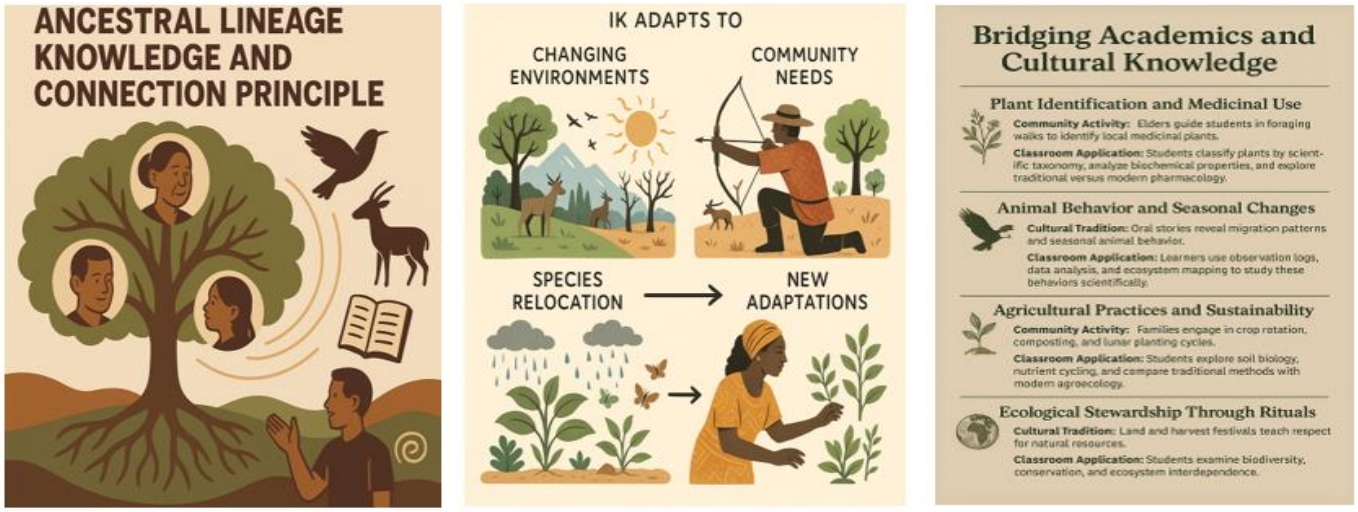

Figure 1: Principles of the TALSc.: Ancestral lineage knowledge and connection to environment, adaptation and flexibility principle & knowledge in action principle.

4.2. Core Principles of the TALSc. Theory

4.2.1. Ancestral Lineage Knowledge Connection to Natural Environment Principle

The TALSc. acknowledges that the most ancestral knowledge is passed through family lineages, indigenous knowledge (Bergström, 2021), and their natural environment. For instance, the study of animal behaviour through observations, to predict weather patterns points to ancestral wisdom that is orally passed to younger generations. The use of medicinal plants to treat ailments is passed down by knowledge keepers to the next generation e.g., the use of a traditional herb imphepho (*Helichrysum spp.*), for treating wounds, respiratory issues and cleansing the environment, a spiritual role before one communicates with the ancestors. So, the elders pass the knowledge on how impepho is identified amongst the other plants, harvested and prepared with honour and respect for spiritual realms and the land. This reflects a profound understanding of sustainable use of a wide variety of medicinal plants. Indigenous people usually read natural environment telltale signs to predict weather patterns. This includes ants' behaviour, blooming patterns of trees and birds' migrations to inform indigenous communities when to plant or when to harvest acquired through story telling.

Ancestors also practiced observing animal behaviour. For instance, when ants, snakes and colourful birds starts to appear more frequently it signalled warmer months approaching. Sparrows and frogs croaking to predict rainfalls. These were shared in everyday lives of indigenous families by elders in the family in a form of songs, stories and lived experiences in the natural environment.

The connection of animal science and word of mouth promotes better understanding of the content. As such, the theory advocates that Life Sciences cannot be taught and learned with understanding apart from cultural teachings passed down from generations to generations. By integrating this knowledge in the Life Sciences teaching practices, pre-service teachers and learners will be encouraged to honour cultural teachings Jacob, Livermore, Sabzalian, Anderson, Sutterlict, Muniz & Beavert, (2025), and see themselves as caretakers that are responsible for caring for cultural and earthly life while acting as knowledge transmitters to our next generation.

4.2.2. IK Adaptation and Flexibility Principle

The TALSc. framework argues that these cultural teachings like, are not static but evolve through the living memory of indigenous communities, making them both timeless and adaptive. Family lineage changes due to ethnic groups intermarriages for instance when a white person marries a black person, which brings about new languages, new blended traditional customs and mixed ancestry, and changing family identities.

TALSc. supports the flexibility of Indigenous Knowledge, which adapts to the ever-changing ecological environment, and indigenous community needs. As the natural habitats and its ecosystems evolves, indigenous communities encounter new challenges to solve and learn new experiences (Molnár & Babai, 2021). For instance, climate change brings rising temperatures on earth, this changes the breeding patterns of animals which eventually alter the cultural practices like hunting and fishing seasons for human consumption. Heavy and prolonged rainfalls like this year, 2025, these prolonged heavy rains drove other species to extinction from their places of origin, pioneering to areas with a smaller number of rainfalls, increasing a new number of weed species that challenges the growth of indigenous plants in the area. This forces traditional healers to seek for indigenous herbs from other places they are not familiar with.

Indigenous knowledge adapts to an ever-evolving technology where modern farmers now uses drones and GPS to monitor crops and farm stock in their fields (Guebsi et.al., 2024). or use helicopters to drive cows from the veld to the kraals, blending ancestral wisdom of traditional cattle farming with technology. Using podcasts, indigenous knowledge applications and social media platforms like Tik Tok, Facebook, Twitter and Instagram could be an advantage for Life Sciences educators to teach learners about their documented heritage, highlighting IK flexibility. To brew traditional beer "*umqombothi*" our grandmothers normally took seven days or so, but now we can easily buy "*umnandi powder*" mix it with lukewarm water in a calabash and get fermented beverage within 24 hours, marking adaptability of IK to modernity.

Human population is ever increasing, which puts a high demand on clearing forests for places to build houses and factories to sustain the growing population (Cassina & Gachara, 2023). However, deforestation, although reshaping landscapes for the benefit of human dwellings, it sometimes wipes off a wide range of indigenous species, which eventually become extinct, forcing indigenous communities to modify where they seek shelter and how they gather food.

In Life Sciences, this TALSc. framework advocates that the teaching and learning of plants, animals, and their habitats should be taught with an understanding that Indigenous Knowledge is not fixed. The behaviour of animal species as they react to climate change, or the medicinal uses of plants according to Sawicka et.al., (2025), may change depending on the circumstances that forces new adaptations. TALSc. framework therefore encourages pre- and in-service teachers as well as learners in schools to engage not only with scientific facts but with the living practices that make indigenous knowledge relevant in their everyday life experiences.

4.2.3. Indigenous Knowledge in Action Principle

The TALSc. advocates that ancestral knowledge extends beyond the four walls of the classroom as it takes learner active involvement to manifest itself. According to Knowledge in Action principle the renewal of indigenous knowledge occurs each day through cultural traditions (rituals and ceremonies) combined with native community activities and oral storytelling practices. Teaching and learning practices in classrooms provide learners with effective methods to apply academic material to real-life situations. For instance, a scientific study on plants and animals will be studied in conjunction with cultural rituals, seasonal festivals, and community healing practices. The following practical examples of Life sciences content demonstrate how daily renewal of indigenous knowledge through Zulu cultural traditions; community activities and storytelling can be effectively applied in Life Sciences classrooms. These examples help bridge academic content and community-rooted knowledge, creating a context-rich and culturally relevant learning.

In Life Science content, plant identification, classification and medicinal use, the teacher may ask learners to group or classify these plants using Carl Lenneaus's scientific taxonomy as a form of classroom application (Kunhikannan, 2025). As part of community involvement community elders may be invited by schools to provide lectures and guide learners on how to identify medicinal plants used in traditional medicines and then invited to critically think and compare the contemporary medicines with traditional medicines.

Life sciences learners can explore animal behaviour, seasonal changes, and environmental sustainability using scientific methods like hidden cameras and ecosystem mappings. They can engage with indigenous communities to learn about animal migration patterns and learn about traditional agricultural practices like crop rotation and natural composting. In the classroom, students can explore conservation of natural resources and protect biodiversity through ecological ownership rituals. In health, healing, and the human body, teachers can provide scientific lessons on organ harmony and group discussions based on balanced diet and wellness practices. Community elders can impart oral histories of ancestral knowledge of natural remedies, allowing learners to become actively engaged in knowledge creation and connecting their learning to their heritage.

5. HOLISTIC APPROACH TO LIFE SCIENCES

The IK in Action principle of TALSc. informs the holistic approach to Life Sciences teaching, by connecting *scientific* and *Indigenous Knowledge* alongside *natural environment, spirituality* and *ancestry*.

5.1. Spirituality: Spiritual and Biological Interdependence

Life sciences together with plant studies and animal research and ecosystem investigations belong to an overall spiritual framework which views each biological entity as sacred being with spiritual essence. Human health in this framework is not viewed as a biological concern but emerges from an interconnected perspective of biology and ecology, which upholds that land and ecosystem wellness causes both biological and spiritual well-being. The world has a sacred structure which exists as a web of interconnected elements. Every plant and animal along with their related ecosystem contain biological characteristics while maintaining spiritual value. Educating pre-service teachers and learners in Life Sciences becomes a purpose of spiritual appreciation and accountability after recognizing this dual nature.

5.2 Natural Environment: Medicinal Plants and Rituals

The examination of medicinal plants along with traditional practices embodies more than biological and chemical properties in their effectiveness. It combines biochemical testing methods with traditional spiritual beliefs and cultural practices regarding the medicinal species. Research programs encompass scientific evaluations together with cultural analysis to furnish students with complete knowledge about medicinal properties that support human well-being and environmental health (Al-Worafi, 2024). The proposed framework suggests inclusion of both traditional and ancestral rituals along with sacred ceremonies together with the stories connected to plants, which maintain cultural importance in science teaching. Students learn about medicinal properties, ritualistic and storytelling traditions regarding plant species during their study. The TALSc. educational model integrates spiritual teachings with biological information to construct an educational program that maintains authentic parity between both fields of understanding.

The changes in environmental patterns represent something greater than biological repetition. These hold religious importance because they link to both ancestral rituals and environmental life cycles. In this tenet, students learn about seasonal patterns from both natural scientific and cultural angles since these recurring times correspond to moments when people seek spiritual links to nature and celebrate harvest periods and native events which follow natural environmental cycles. The proposed TALSc. approach connects Life sciences, geography and agricultural sciences about climate change to the sacred practices that correspond to natural cycles. For instance, indigenous people knows when it's time for planting or harvest when pointers like a type of flowers are blooming or certain birds are coming back, or migration of certain herbivores is in process. Nowadays when we see pink and white flowers blooming and spreading all over during April month, it's a telltale sign that Easter time is approaching, or prolonged rainfall season signals for the upcoming of extremely cold winter months, teaching us how Life Sciences and spiritual observance co-aligns.

The understanding of seasons exists both scientifically and spiritually since these periods match biological cycles as well as sacred tribal cycles of birth and transformative immortal passage. The educational system integrates agricultural, ecological and spiritual calendars to demonstrate how cultural practices respect natural rhythms of nature.

5.3. Ancestry: Ancestral Teachings

The indigenous people according TALSc. framework see animals as intelligent teachers who serve as spiritual messengers

from their ancestors. For instance, seeing butterflies entering your space in times of turmoil suggest protection from ancestors and good luck, while bees may symbolise abundance and suggests collaborations with others in your working spaces. While these insects may predict good omen approaching in ones' life, other animals like sparrows may signal for environmental changes e.g. sparrows flying overhead, in groups just before it rains symbolises oncoming rain, and the presence of brown snake at home symbolises the presence of the ancestors. Environmental research of animal behaviour involves studying traditional tales together with omens and sacred teachings while exploring modern ethology which creates an enriched understanding of both approaches and their significance. Analysing animal behaviour requires knowledge that extends beyond biological studies to include ancestral teachings which explain animal connections with family lines and spiritual knowledge. Zulu culture perceives some animals as spiritual instructors who deliver essential wisdom to the communal group. Educational content will investigate how scientists study animal behaviour (feeding, nesting, migration) in addition to exploring traditional ancestral teachings that describe interdependence.

5.4. TALSc. Proposed Curriculum Application and Implementation

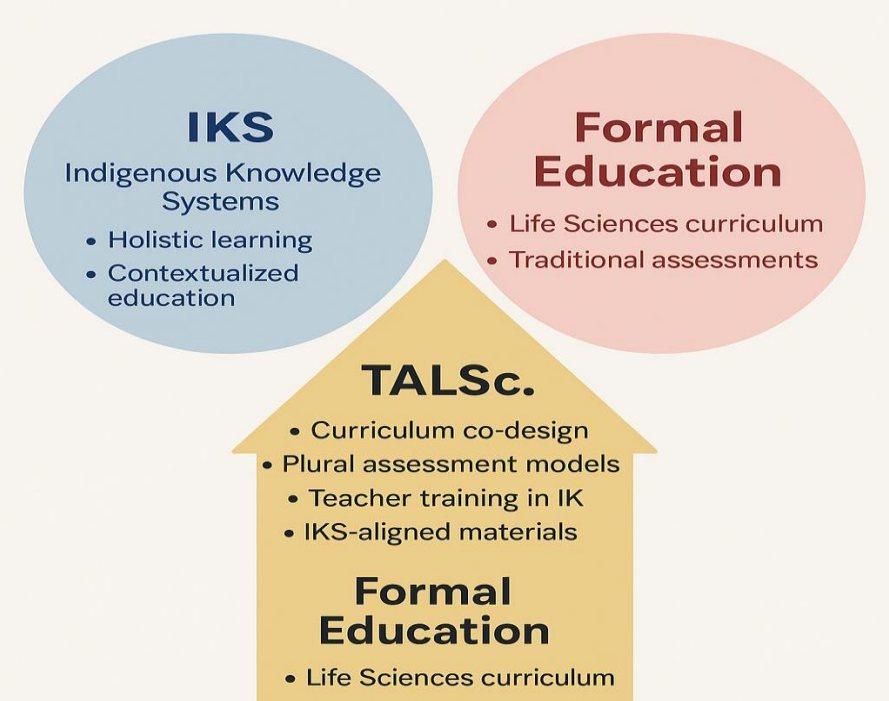

Figure 2: TALSc. Proposed curriculum application and implementation.

To achieve this suggested implementation the following aspects, need to be taken into consideration:

- Epistemological Justice: Recognising and valuing different ways of knowing, including Indigenous, ancestry, spiritual and ecological viewpoints.
- Contextual Responsiveness: Teaching Life Sciences concepts in ways that relate (relational learning) to learners lived environments, experiences and community histories.
- Dialogical Pedagogy: Fostering co-construction of knowledge through dialogue between teacher, learner, IK community elders, and CAPS scientific curriculum.

5.5. TALSc. Methodologies for IK Integration

It is not always easy for teachers to use clear procedures that integrate Indigenous knowledge, as well as Western viewpoints in Life sciences teaching practices. TALSc. developed a simple step by step framework to explain how to integrate both Indigenous and Western knowledge systems in a lesson plan. TALSc. is of the view to develop and provide complete teaching materials that clearly endorse the blending of Indigenous and Western knowledge systems. Because tangible solutions could be developed through the Indigenous elders and educators by participation in workshops, it is essential for Indigenous elders and educators to interact during workshop settings.

Teachers' ought to make sure that Life sciences lesson plans have clear examples of teacher and learner activities, and assessment in which Indigenous and Western perspectives are blended. For instance, a teacher may come up with three lesson objectives: Scientific, Indigenous Knowledge and Integration lesson objectives as a point of departure. These lesson objectives forms part of lesson development or presentation, which should ultimately be tested in a form of summative and formative assessments. Below is a practical example of a lesson that connects the two perspectives:

Table 1: TALSc. strategy for ik integration in bacteria lesson plan.

Lesson Plan: Microorganisms (Bacteria)
Grade: 11
Subject: Life Sciences
Duration: 120 minutes
Topic: Understanding bacteria through Scientific and Indigenous practices OR
Microorganisms in the Environment (bacteria & human use)
Lesson objectives:
At the end of this lesson, learners will:
Scientific objective

1. Understand what bacteria are, including their structure, types, and roles in ecosystems as per CAPS requirements.
2. Describe the role of bacteria in fermentation according to CAPS curriculum.

Indigenous knowledge objective

3. Explore how Indigenous Zulu practices have traditionally utilized bacteria in food, health, and environmental stewardship.
4. Discuss how traditional knowledge in the use of bacteria contributes to modern scientific understanding.

Integration objective

5. Compare traditional and scientific understandings of bacteria and their uses.
6. Compare Indigenous fermentation practices with commercial biotechnology in breweries.

Learning and Teaching Support Material (LTSM)

- Microscopes or images of bacteria
- Samples/photos of fermented foods (e.g. amahewu, sour milk/amasi)
- Chart paper and markers
- Images or samples of traditional cleansing plants (e.g. impepho, isiwasho)
- Audio/visual materials showing traditional food preparation or healing rituals e.g. acupulture

Teaching strategies:
Teacher-centred approach
Learner-centred approaches
Teaching Methods:

Teacher-centred approaches: Demonstrations, illustrations, lecture method
Learner-centred approaches: Group discussions, experiments, presentations
LESSON PRESENTATION

1. introduction (10 minutes)
Start with prior knowledge activation:
Ask learners:
"Have you ever drunk amasi or seen how amahewu is made? What do you think causes them to change or 'go sour'?"

- Show a short video or image sequence of amahewu or amasi preparation.
- Guide discussion towards

Spiritual and Symbolic Aspects:

- In Zulu culture, fermented foods like amasi are not just nourishment—they connect people to ancestors and traditional knowledge.
- Smoke from burning impepho during rituals is thought to "cleanse" spaces—modern science shows some bacteria are airborne; smoke may have had antimicrobial properties.

microorganisms. Introduce bacteria as microscopic life that can be helpful or harmful.

2. lesson presentation (15 minutes per objective)

Scientific objective

Teacher activities
(Objective one – 15 mins)
2.1 What Are Bacteria?

- Teach learners about the role of lactic acid bacteria (e.g., *Lactobacillus*) in fermentation.
- Explain how fermentation is a metabolic process carried out by bacteria under anaerobic respiration conditions.
- Link this to human microbiome health and biotechnology (e.g., antibiotics like penicillin and food production).
- Define bacteria: single-celled organisms found everywhere—in soil, water, food, and the human body.

Learner activities
Classroom activity 1:
Investigation or Demo: Prepare a simple fermented food (e.g., yogurt or fermented maize) and observe the role of bacteria over several days.

Classroom Activity 2: Observation & Classification
Learners will identify and classify different types of bacteria by shape and function, using visual aids and examples.
Instructions:

1. Provide images or slides of various bacteria (e.g., *Lactobacillus*, *E. coli*, *Rhizobium*).
2. Learners complete a table with the following columns:
   - Name of Bacterium
   - Shape (rod, spiral, spherical)
   - Beneficial or Harmful
   - Where it's found
   - Role (e.g., fermentation, digestion, nitrogen-fixing)

Example:

- Show visuals of different types (rod-shaped, spiral, spherical).
- Differentiate beneficial vs. harmful bacteria.
- Examples:
  - *Lactobacillus* in fermented milk
  - *E. coli* in digestion (and sometimes illness)
  - Nitrogen-fixing bacteria in soil

Bacterium	Shape	Beneficial/Harmful	Location	Role
Lactobacillus	Rod	Beneficial	Fermented milk	Helps in fermentation
E. coli	Rod	Both (contextual)	Human intestines	Aids digestion; can cause illness

Indigenous knowledge objective
Teacher activities

(OBJECTIVE TWO – 20 mins)
2.2 Lessons' description:
Many Indigenous communities around the world, including African, Asian, and South American cultures have used fermentation process for generations to prepare beverages, preserve food and promote health. These methods rely on beneficial bacteria, such as lactic acid bacteria, to break down food and prevent its spoilage without refrigeration.
Examples include:

- Amahewu or Mageu (fermented maize drink in Southern Africa)
- Umqombothi (fermented traditional beer "umqombothi" in Africa)
- Amasi (sour milk), and other traditional fermented foods

2.3 Indigenous Zulu Practices Involving bacteria
Practical Demonstration

- Show a jar of raw milk turning into amasi over 2 days (or photos over stages).
- Use simple microscope or prepared slides to view bacteria or show diagrams.
- Let learners smell or taste amahewu or fermented foods (if available and safe).

Learner activities

Classroom Activity 1:

- Discussion Prompt: "How do Indigenous fermentation practices show early understanding of microbiology?"

Group Activity 2: Cultural Case Studies
Break class into 3 groups. Each group explores one traditional practice involving bacteria.

GROUP 1	GROUP 2	GROUP 3
Amasi	Fermentation of Amahewu	Cleansing & Protection Rituals (Impepho / Isiwasho)
Fermented sour milk using lactic acid bacteria (LAB).	Fermented maize drink using wild bacteria and yeast.	Herbal mixtures for bathing or burning; believed to purify and protect—may have antimicrobial effects.

Example Answer for GROUP 1: Amasi
1. What is the traditional practice?
Keeping raw milk in a cool container (often a calabash or clay pot) to allow natural fermentation into amasi.
2. Which natural process is taking place?
Lactic acid fermentation: bacteria like *Lactobacillus* grow and convert milk sugars into lactic acid.
3. How does it relate to bacteria?
The souring of milk is caused by bacterial action, preserving it and enhancing digestion. Traditionally seen as healthier and spiritually nourishing.

Integration objective
Teacher Activities
(OBJECTIVE THREE – 20 mins)
2.3 Class Discussion Questions:

- How does science explain the same things our elders knew long ago?
- Why is it important to respect and study Indigenous knowledge in Life sciences?
- Are traditional methods more eco-friendly than some modern ones?

Learner Activities
Compare Traditional and Modern Uses
(OBJECTIVE THREE – 10 mins)
Learners create a comparison chart/poster that compare traditional and scientific understandings of bacteria and their uses.

- Traditional fermentation vs. modern food fermentation
- Natural soil management (e.g., using compost with microbes) vs. chemical fertilizers

ASSESSMENT

3.1 (Scientific Objective One): Classwork
Learner's answer in notebooks

1. Name ONE type of bacteria and its role.
2. What are bacteria? Name types of bacteria that you know.
3. Draw the structure of a bacteria.
4. Describe the role of bacteria in the ecosystems.

5. Name one indigenous practice that involves bacteria.
6. Explain how Indigenous knowledge shows awareness of bacteria.

3.2 (Indigenous Knowledge Objective)

Presentations:

3.2.1 Each group presents their case study findings.

3.3.2 Explore how Indigenous Zulu practices have traditionally utilized bacteria in food, health, and environmental stewardship.

3.3 (Integration Objective): Project (poster design)

3.3.1 Research Project:

Allow learners to compare traditional vs. industrial fermentation, focusing on the role of bacteria.

3.3.2 Design a poster that compare beneficial and harmful bacteria:

(i) Why is it important to know both helpful and harmful roles of bacteria?"

(ii) Traditional and scientific understandings of beneficial/ good bacteria and their uses.

(iii) Traditional and scientific understandings of harmful/bad bacteria and their treatment

Table 1. A lesson plan on understanding bacteria through Scientific and Indigenous practices/ Microorganisms in the Environment (bacteria & human use).

Educators should be supported with appropriate training manuals, guidebooks and the resources of the two systems integration which help create learning experiences that value both Indigenous and Western knowledges. Workshops collaboratively conducted among Indigenous scholars and scientists provide educators with productive insights for blending both Indigenous and Western perspectives into classroom environments. Whenever possible, it crucial to create classrooms where Indigenous knowledge keepers work with Life sciences teachers to teach lessons. With collaboration in real-time, it is possible for educators to create methods to combine indigenous and western perspectives flawlessly in lesson plans.

5.6. Contextualized Life Sciences Learning

TALSc. teaches learners through contextualized learning by using the ecosystem combined with historical and cultural practices as educational foundations. For instance, when learners explore biological properties and traditional uses of medicinal plants like sutherlandia and chamomile, they integrate and bridge the gap between botanical science (branch of Life Sciences), and ancestral wisdom for healing. Deepening the understanding of both scientific and indigenous knowledge perspectives. In rituals linked to environmental cycles, through the study of human physiology learners explore the coming-of-age ritual (*umemulo),* which connects girls' puberty to the seasonal cycles in their environment. These traditional ceremonies are held when its warmer following the seasons after harvest when there's abundance, and families have a greater access to plenty of food for invited guests and seasonal availability of livestock to provide *umhlwehlwe* for the ritual. The understanding of the human body structural functioning (puberty) and natural environment cycles becomes possible through TALSc. connection.

The Life Sciences CAPS curriculum examines community biodiversity by teaching about plants alongside animals and natural systems which form part of the cultural environment. Learners may be given cultural project that requires practical investigations that involve the seeding of local crops such as *ubhatata* and *amadumbe* applying traditional Zulu farming practices. The cultural nature of this instructional method gives Life Sciences classes a practical significance through connections of students' ancestral wisdom (traditional ploughing) and science (soil science) educational value for them. The TALSc. educational approach maintains its foundations in the local ecosystems while utilizing historical and traditional elements from the region which establish profound student-to-environment connections. Zululand's rich biodiversity and cultural heritage serve as living laboratories for integrated learning.

5.7. Elder-Led Education and Storytelling

The Life Sciences curriculum requires a direct involvement of community elders and knowledge holders for student teaching purposes. Educators consider elders along with cultural knowledge holders to be essential for teaching roles. They conduct storytelling events and perform ritual-based learning procedures to deliver scientific wisdom which exists within cultural contexts. Community elders may take fieldtrips with learners to identify medicinal plants like *inkalane* and *ibhucu,* in which the scientific approach can identify their cosmetic and healing properties, linking ancestral wisdom with modern cosmology and pharmaceutical use of these plants. Students may also get involved in ceremonial practices around water for instance virgins' traditional visit to the mountain asking for rain from *Nomkhubulwane* under the guidance of the community elders or arranged fieldtrip visits to sacred places like Dingane's spring near Ulundi. Followed by a modern way of performing water tests experiments in the lab for microorganisms' content e.g. bacterial content. Furthermore, elders may narrate how they kill livestock (cattle and goats) and prepare them for human consumption during traditional ceremonies. This can open an avenue of dissecting animals (zoology) where learners may practically learn and take note of different parts of the skeleton, different systems and associated organs. Comparing physiological structure of an animal and traditional insights from elders, while appreciating the connection of the two perspectives. The TALSc. in this way, is an educational approach that enables students to participate in intergenerational learning that depends on lived memories (wisdom) which surpasses Life sciences textbook content knowledge.

5.8. Fieldwork and Ecological Immersion

Fieldwork trips and ecological immersion experiences are always a joy to learners. Learners become hands-on while constructing knowledge on their own. After immersion in the natural environment (ecology), students may be guided by educators to observe and experience the natural world of their local community. Under traditional healers' supervision and teachers' guidance, students may start identifying and collecting medicinal plants, mapping locations where they are found, and listening to traditional stories, songs and rituals shared by elders around those plants, emphasizing respect and sustainability. Or even listen to the cultural teachings of animals' symbolism and their role in the community life, that is, after having been initially exposed to fieldtrips that allows them to study animal behaviours like migration seasons, parental care, feeding, and interaction with environment. The field works according to TALSc. enable students to discover Life sciences as an active exploration joining

spiritual wisdom to scientific research.

5.9. TALSc. Alignment with Life Sciences CAPS Official Curriculum

TALSc. encourages a Holistic Curriculum Design, departing from a broad, generalized Indigenous knowledge and bring in unique Indigenous epistemologies to Life sciences discipline like environmental science, literature, and health. For example, a teacher may not separate ecological practices and stories held by different indigenous communities as both equally deserve to be taught in the school curriculum. Working with the Indigenous elders actively guarantees that any knowledge shared is true and it also keeps the significant community perspective. The TALSc. further advocates to work with educational Life sciences curriculum planners in designing flexible IK models of assessment which formally accredits experiential and community-based learning as meaningful ways of gaining knowledge. One possible way is to make a combined IK and Eurocentric credentialing options that acknowledge multiple forms of learning and assessing.

5.10. Systemic Institutional Resistance to IK Integration

Sometimes resistance to integrating Indigenous knowledge into Life sciences education modules in Higher institutions and schools' rests in the general acceptance of Western epistemologies. Working with the policymakers to create educational policies that demand adoption on Indigenous Knowledge. Such efforts may include setting clear rules and procedures to promote and appreciate diversities of cultures by cooperative means. For example, universities and school divisions could require that teachers taking part in professional development courses apply Indigenous knowledge in their classroom teaching practices as suggested by CAPS specific Aim 3. These institutions may partner with Indigenous groups in generating the curricula related to combining themes and ideas from life science, natural science, social science, and humanities from an Indigenous point of view. A central role of Indigenous elders or knowledge keepers in curriculum design is crucial to a realistic and detailed representation of their knowledge systems. The potential solution suggested by TALSc. to this gap is to enact Higher institutions guidelines for fostering cross-cultural educator training modules in Indigenous knowledge systems and make Indigenous knowledge holders (elder, community leaders) part of education projects.

5.11. TALSc. Assessment Methods

TALSc advocates for a holistic assessment approach that incorporates ancestral wisdom in education. They suggest introducing formative assessments that measure collaborative skills, social-emotional growth, and community membership. Teachers can create rubrics that focus on cultural values and collaboration skills. Curriculum planners can design Life science curriculum to include Ubuntu values, emphasizing ecological responsibility and the organic link between human and environmental health. Educators should allow learners to express their stories and experiences, align learning with their lived reality, and support teacher training programs that integrate Ubuntu pedagogy into Life sciences programs.

5.12. Pre-service Teacher Training

The TALSc. framework aims to bridge the cultural competence gap in teaching Life Sciences by designing curriculums with indigenous knowledge systems (LTSM) and involving community elders, indigenous knowledge holders, and teachers. This includes incorporating traditional assessment methods, storytelling, and investigations into indigenous communities, allowing learners to immerse themselves in their daily activities. Higher education facilities should also incorporate IK integrated curriculum programs into their Life Science education training modules to make the framework a living practice in classrooms.

5.13. Spiritual and Ecological Knowledge is Often Overlooked as a Main Subject by the Educational System

The integration of Indigenous spiritual and ecological views is usually omitted in formal educational environments. TALSc. is of the view to popularize the study of ecological ethics, sustainability, and spirituality through Life sciences academic curriculum and equalize them with the analysis of natural systems with empirical and scientific practices. One strategy for addressing this might be clarifying Indigenous ecological thoughts in the study of biology and environmental science.

TALSc. advises Life sciences teachers to develop teaching plans which synthesize Indigenous perspectives regarding spirit, ecology and environmental responsibility. Course offerings in biology, geography, and environmental science can include the Indigenous perception of sustainability and relationships between people and the environment. They may furthermore create land-based learning projects in which learners create relationships with their surrounding environment and use Indigenous knowledge systems to examine ecological concepts. Examples of activities are field trips, aiding in community gardening, and working with Indigenous groups on traditional ecology seminars.

Merge conversation regarding spirituality and ethics related to environmental sustainability and human influence with Life sciences lessons and show its implications for responsible scientific conduct by emphasizing how spiritual understandings of life's connectivity influence scientific practice. For example, in the topic of Human Impact on the environment, discuss the effects of human activities on earth's environment including pollution and climate change. Identify three lesson objectives to build your presentation and base your assessments on.

Example: IK Lesson Integration: Human impact in environment (Topic).

1. Science Focus Objective: Analyze greenhouse gases, investigate deforestation trends, and look at the problems related to excessive waste management as required by CAPS curriculum.
2. Spiritual & Ethical Link/IK Objective: Present learners with Indigenous views or religious traditions that regard the Earth as sacred and see people as guardians rather than possessors.
3. Integration Objective: Engage the class in discussions and presentations. Discussions could be based on critically analysing and comparing the two perspectives.

5.14. Power Dynamics in Knowledge Sharing

TALSc. advocates for the co-creation of Life sciences teaching and learning materials, involving indigenous communities in

curriculum planning and development. They advocate for equal value between Indigenous and Western knowledges, treating Indigenous knowledge as a peer in the corpus of knowledge. TALSc. supports organizing IK empowerment workshops to empower Indigenous communities to represent their knowledge system independently of Western educational standards, preserving their unique knowledge in their own terms. This approach promotes a more inclusive and effective approach to science education.

5.15. Inclusivity and Diversity

While TALSc. is based on Zulu cultural examples; the framework is inclusive to all the ethnic groups in Africa and applicable globally. In this way the space for participation by different indigenous cultures throughout Africa and international is not limited. The intercultural blending enables investigating means of managing and promoting cooperation among Life sciences educators of different backgrounds for instance in the multicultural classrooms like in the urban-rural classes. Context-specific integration connects with Indigenous groups in a direct manner, to ensure that traditions and languages, and customs are appropriated in the correct manner. The use of a culturally sensitive TALSc. model, adapted to every ethnic group instead of a rigid “Indigenous Knowledge” model, is necessary. The recognized knowledge systems, customised for each Indigenious community, are necessary for their integrity maintenance.

5.16. Student-Centred Implementation

Although the issue of cultural transmission is being emphasized, the TALSc. theoretical model defined how learners can interact, to analyze or work in the path, with indigenous knowledge, instead of just consuming it. Example:

Through the TALSc. model, the learners are promoted to be active participants in the quest for Indigenous Knowledge as opposed to being passive consumers. For instance, in a Grade 11 Life Sciences lesson focused on medicinal plants, learners would not merely recall that Sutherlandia is used traditionally for the boosting of immunity, but would interview indigenous people, compare with the findings with scientific research and discuss such ethical issues as sustainability and biopiracy. This method cultivates students’ critically thinking skills, cultural respect, and integration of scientific knowledge with knowledge of the indigenous population, which is consistent with the aim of the model to turn learners into co-creators of the knowledge. The experience of many urban students all too often alienates them from the cultural traditions they come from. Program strategies in TALSc. in classroom practices might assist urban students in perceiving ancestral knowledge as significant and relevant to their everyday life.

5.17. Spaces for Connection with Indigenous Knowledge Keepers

Indigenous wisdom-holders access is limited, particularly for most inhabitants in remote locations. TALSc. is of the idea of audio and video recording their narratives or use live virtual platforms and technology wherein Indigenous knowledge keepers can express their oral histories, stories and teachings. Doing this can bring Indigenous wisdom into the Life sciences classrooms across the world without needing long trips. TALSc. is of a view to design Indigenous Knowledge sharing hubs be it in school or neighbourhood spaces for sharing of Indigenous knowledge to which the elders should be able to come and share their traditions through this facility with the younger ones. Some of the options are videos of elders, undertaking webinars or write an online course about the teachings of Indigenous elders and community leaders. Indigenous cultural centres in Schools can also go a long way to help connect with Indigenous community partners to establish a cultural centre in a district or school such that students have opportunities to experience hands-on, live learning around Indigenous culture.

5.18. TALSc. Model in Addressing Technological Gaps

TALSc. is of the idea to create online educational platforms and collaborative efforts among communities for Indigenous elders to participate virtually. Digital resources such as podcasts and social media, create a way technology can be easily integrated in facilitating learning of TALSc today in Life sciences classrooms. With the aid of digital technologies in the form of learning management systems, live interactive simulations, gamification, and collaboration tools (such as Google Workspace, Google Meet or, Microsoft Teams), important skills, such as critical thinking or collaboration, and digital literacy are promoted. Virtual simulations can bring students inside real-world sustainability conundrums, and data analysis technologies allow them to realize system complexities while manipulating environmental information. Strategic use of social media tools can leave Life sciences students capable of operating in civic activities and collaborating globally, essential aspects of the sustainable education puzzle. Lack of an ordered approach to weave these resources into school curricula may undermine their ability to facilitate interaction, create personalized instruction, and enable students to attain a deeper understanding of ecological issues.

Once exposed to such collaborations in Life sciences teachers can easily merge Indigenous and Western methods of education by illustrating oral traditions and stories in user-friendly online platform such as podcasts, videos and classroom.

6. PARADIGM FOR LIFE SCIENCES

The Theory of Ancestral Life Science (TALSc.) rejects the division between modern sciences and ancestral wisdom while offering combined educational methods for Life Sciences learning. Ancestral knowledge deserves respect alongside dynamic Indigenous Knowledge Systems, and daily practices that contain living memory thus providing biology, ecology/natural environment and indigenous knowledge as one holistic system. Memorizing science concepts lacks depth because scientists need to establish alignment between their knowledge of science and the land while maintaining strong family and ancestral ties to create future Life Sciences knowledge that connects to modern relevance and historical grounds.

7. THE CIRCLE OF ANCESTRAL LIFE SCIENCES (TALSC.) MODEL

The TALSc. Model consists of a sacred circle at the centre, having six interconnected components which embody three cultural teaching or central principles from Ancestral Life Sciences Theory. All elements within the "**Living Heart of Knowledge**" unite as the central focal point in the model.

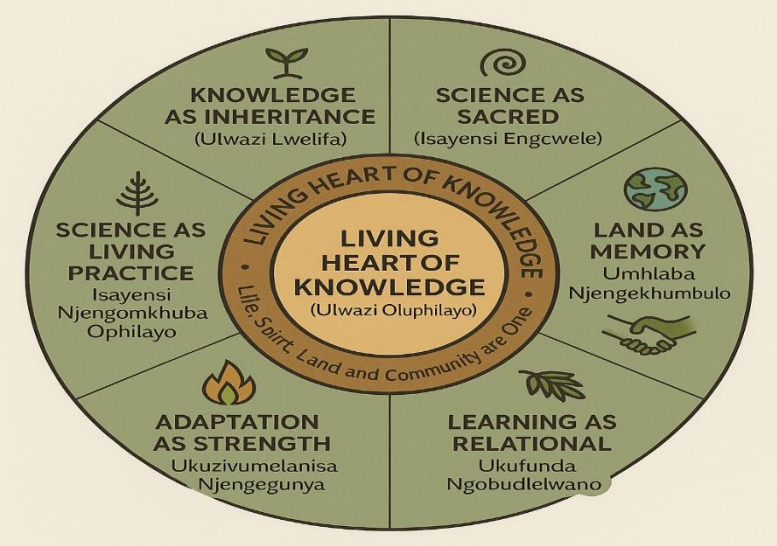

Figure A2: The circle of ancestral life sciences model structure.

Table 2: Meanings of the six sections of TALSc. Model.

THE meaning of six sections of TALSc. Model around the center
Central circle symbolises a Living Heart of Knowledge (Ulwazi Oluphilayo). According to a living heart of knowledge, *life* and *spirit* exist as one with the *land* and *community.*
Knowledge as Inheritance (Ifa lolwazi)
Living communities receive knowledge from their family lineages of ancestors.
Life Science as Sacred (Isayensi engcwele)
Learners to respect the spiritual nature of Life Sciences as it holds sacred value.
Land as Memory (Umhlaba njengenkumbulo)
Through land ancestry stories learners find their place of origin and ancestral legacies get transmitted.
Learning as Relational (Ukufunda Ngobudlelwano)
The growth of knowledge occurs when community members build connections through their social relationships.
Adaptation as Strength (Ukuzivumelanisa Njengegunya)
Aboriginal knowledge exists as a flexible living system which continues to evolve.
Science as Living Practice (Isayensi Njengomkhuba Ophilayo)
Everyday life together with ceremonial practices serve to perform knowledge.
Outer Circle
Ancestral authority has established a permanent protective system which ensures a continuous knowledge transmission from generations to generations.
Visually
The design indicates a living cycle which converges all sections to the central point (The Living Heart of Knowledge) while operating dynamically through continuous movements.

8. ETHICAL CONCERNS

Implementation of Indigenous Knowledge (IK) in academic or research environments tends to pose huge intellectual property and ethical problems, primarily involving ownership, participants' consent and safeguarding culturally sensitive information (Khazamula, 2025). Reversing the individualistic character of Western patent and copyright laws, Indigenous Knowledge tends to be owned and transmitted as a whole, in spoken forms, and vital to cultural and spiritual existence. Either taking or using IK without IK holders' consent by obtaining free, prior and informed consent is likely to misrepresent and take advantage of IK, particularly if essential sacred or community specific elements are misused or commercialized. These international agreements, UNDRIP and the Nagoya Protocol, reflect the important role which denotes honour of Indigenous peoples' sovereignty and control over traditional knowledge (Aroian,2025).

9. RECOMMENDATIONS

Several factors make the circle of Ancestral Life Sciences Model an intelligent choice for adoption. This model follows the perspective based on Indigenous cultural traditions which are cyclical, relational and dynamic. Life Sciences demonstrates that its progression follows an organism's natural processes of continuous change and life development. Learners together with pre-service educators and researchers find it simple to comprehend and use this model in their work. The ancestral traditions remain honoured through this circular structure which reflects typical gatherings of community and rites and the worship of ancestors.
Training Life sciences teachers correctly is necessary since educators must possess both mastery of dependable resources and the ability to teach with respect for diverse cultures. Joint training programs with Indigenous knowledge holders and those teaching science can be used to show teachers effective ways to apply land-based learning and Indigenous knowledge in their classrooms. Concrete instances involve schools joining with local Indigenous groups to design lessons together, or having Elders lead students during field trips focused on Indigenous ways of understanding nature.

10. CONCLUSION

The Theory of Ancestral Life Sciences (Izimfundiso Zomdabu Zokuphila) presents a futuristic approach for restoring both

decolonization and revitalization within Life Sciences. The Theory of Ancestral Life Sciences unites science and spirituality by using ancestral wisdom and living cultural practices and adaptive Indigenous knowledge. This new perspective demands an absolute transformation of how knowledge comes into existence and becomes both learned and practiced while guaranteeing future generations obtain life's genuine practical wisdom. This transformative theory extends beyond educational transformations of Life Sciences to create a worldwide academic demand for knowledge re-evaluation.

REFERENCES

Al-Worafi, Y. M. (2024). *Handbook of complementary, alternative, and integrative medicine: Education, practice, and research volume 3: Research evidence-based clinical practice*. CRC Press. https://doi.org/10.1201/9781003328049

Aroian, M. (2025). Traditional cultural expressions and copyright law: Denoting the long-lasting confusion. *The Journal of World Intellectual Property*.

Bergström, J. (2021). Whose knowledge counts? The struggle to revitalise indigenous knowledges in Guatemala. *Sustainability, 13*(21), 11589. https://doi.org/10.3390/su132111589

Bolwerk, A. (2021). *The rocky shores of Prince of Wales, Alaska: Intertidal ecology, abalone, and community sustainability* (Master's thesis). University of Alaska Fairbanks. https://scholarworks.alaska.edu/handle/11122/12539

Cassina, C., & Gachara, R. W. (2023). William Samoei Ruto. Raia Group, School of Politics, Economics and Global Affairs, and RAIA NOW gUG, IE University. https://raiagroup.org/wp-content/uploads/2023/08/1.-IE-School-of-PEGAxRAIA_William-Ruto_Final-Report_By_-Chiara-Cassina-and-Ruby-Wanjiku-Gachara.pdf

Felgueiras, M. L., Tymoshchuk, O., Saborano, S., Breia, I., & Resende, M. (2022). Cultural heritage and education: What relationship? In *EDULEARN22 Proceedings* (pp. 7755–7764). IATED. https://doi.org/10.21125/edulearn.2022

Freire, P., de Sousa Santos, B., Tamale, S., Praeg, L., Chitando, E., Magadla, S., ... & Makua, M. (2024). Pedagogies of the south and ubuntu as feminist decolonial pedagogy. In *Roads to decolonisation* (pp. 281–299). Routledge.

Guebsi, R., Mami, S., & Chokmani, K. (2024). Drones in precision agriculture: A comprehensive review of applications, technologies, and challenges. *Drones, 8*(11), 686. https://doi.org/10.3390/drones8110686

Jacob, M. M., Livermore, W. K., Sabzalian, L., Anderson, R., Sutterlict, T. G., Muniz, H. R., & Beavert, T. V. R. (2025). “You can’t cram for this kind of education”: Centering Indigenous Elder pedagogy to reclaim respectful and socially just education. *Theory Into Practice, 64*(2), 197–209.

Khazamula, X. E. (2025). The role of the Fourth Industrial Revolution (4IR) technologies in digital preservation and documentation of Indigenous Knowledge Systems. In *Revaluation and preservation of Indigenous Knowledge Systems in modern society* (pp. 243–264). IGI Global Scientific Publishing.

Kunhikannan, C., Anju, M. V., & Prasanna, R. (2025). Taxonomy: Importance, relevance and application. In A. K. Mandal & A. Nicodemus (Eds.), *Textbook of forest science* (pp. 65–85). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-8289-5_5

Koopmans, R., & Statham, P. (2010). Theoretical framework, research design, and methods. In R. Koopmans & P. Statham (Eds.), *The making of a European public sphere: Media discourse and political contention* (pp. 34–59). Cambridge University Press.

Lin, F., & Puntambekar, S. (2025). Epistemic scaffolding: Understanding and designing the support for epistemic growth in science. *International Journal of Science Education, 47*(6), 769–793. https://doi.org/10.1080/09500693.2024.2349973

Lynch, J., Ramjan, L. M., Glew, P. J., & Salamonson, Y. (2025). How to embed a conceptual or theoretical framework into a dissertation study design. *Nurse Researcher, 33*(1), 57–62.

Marino, S., & Baldassar, L. (2024). Comusichiamo: First language, life-soundtracks and storytelling to support the cultural wellbeing of migrants living with dementia. *Journal of Intercultural Studies, 45*(1), 1–18. https://doi.org/10.1080/07256868.2024.2418601

Molnár, Z., & Babai, D. (2021). Inviting ecologists to delve deeper into traditional ecological knowledge. *Trends in Ecology & Evolution, 36*(8), 679–690. https://doi.org/10.1016/j.tree.2021.05.002

Nganga, L., & Kambutu, J. (2024). Culturally responsive professional development programs for teacher educators using community-based collaborative learning: Lessons learned from a Native American community. *Education Sciences, 14*(7), 787. https://doi.org/10.3390/educsci14070787

Okpara, G. C., & Ekeh, G. (2025). Rethinking education in Nigeria: Applying Ubuntu philosophy for community-based learning and social responsibility. *Journal of Arts, Religion, Philosophy and Cultural Studies, 1*(1), 1–10.

Sawicka, B., Pszczółkowski, P., Barbaś, P., & Krochmal-Marczak, B. (2025). Adjuvants: Types of adjuvants and their effects on ecosystems in relation to climate change. In B. R. Babaniyi & E. E. Babaniyi (Eds.), *The interplay of pesticides and climate change: Environmental dynamics and challenges* (pp. 31–63). Springer Nature. https://doi.org/10.1007/978-3-031-81669-7_2

Sommer, B. W., & Quinlan, M. K. (2024). *The oral history manual* (4th ed.). Rowman & Littlefield. https://rowman.com/ISBN/9781538181706

Tremblay, M. C., & Martin, D. H. (2023). Etuaptmumk/Two-eyed seeing: A guiding principle to respectfully embrace Indigenous and Western systems of knowledge. In D. Jourdan & L. Potvin (Eds.), *Global handbook of health promotion research, Vol. 3: Doing health promotion research* (pp. 105–114). Springer. https://doi.org/10.1007/978-3-031-20401-2_10

Williams, R. (2024). *The biological framework for a mathematical universe* (Version 3). PhilArchive. https://philarchive.org/rec/WILTBF-7

Yeoh, C.-P., Li, C.-T., & Hou, H.-T. (2025). Game-based collaborative scientific inquiry learning using realistic context and inquiry process-based multidimensional scaffolding. *International Journal of Science Education, 47*(8), 961–983. https://doi.org/10.1080/09500693.2024.2354944