THE CONUNDRUM OF INDIGENOUS KNOWLEDGE IN THE SCHOOL SCIENCE CURRICULUM: A QUESTION OF ONTOLOGY

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ABSTRACT
This article focuses on the ontological similarities and differences between the natural sciences and Indigenous Knowledge (IK). The theoretical paper explores the affordances of IK in the science classroom, and how pedagogies that allow learners to explore the tenets of respectively science and IK could be used. The work is informed by two empirical research projects in which the author was involved. The first mixed-methods study focused on epistemological border-crossing in the science classroom and the barriers that prevent IK inclusion in science themes. The second project, an ethnobotanical and anthropological study on indigenous plant use, using the Matrix Method, produced the Rationality Index of Plant Use (RIPU). The affordances of the RIPU are explored in this paper. The conclusion is that engaging pedagogies, underpinned by problem-based and cooperative learning principles, such as the Kirby-Bauer technique to explore the antimicrobial activity of muthi plants, ethnobotanical surveys, and the RIPU heuristic, hold the potential to provide learners with nuanced understandings of, and appreciation for, Indigenous Knowledge Systems (IKS). This paper provides insights, based on empirical research, on how IK could be promoted in the school science curriculum.

Keywords: Indigenous Knowledge, science education, ontology, ethnobotany, engaging pedagogies

INTRODUCTION
The Latin term, *Respice Prospice*, meaning ‘to look back, to look forward’, reminds us that IK holds many affordances for solving some of the perennial issues facing humankind in the 21st century. One example is the fact that the holders of IK lived in harmony with the environment. With the 2030 Agenda for Sustainable Development (United Nations, n.d.) and the Sustainable Development Goals, it would be wise to consider how IKS traditionally responded to ecological and developmental challenges (Magni, 2017). Also, IK in terms of medicinal plants holds much promise in terms of job and entrepreneurial opportunities. One such example is the traditional use of *Elytropappus rhinocerotis*, the ‘renosterbos’, which is widely used in the Cape to treat foot odour, perspiration, and itchy and burning feet (Hulley, Van Vuuren, Sadgrove and Van Wyk, 2019). Ethnopharmacological studies have shown that the essential oils in the plant are highly effective against Brevibacteria, which cause foot odour. This is but one example of ethnobotanical knowledge that holds economic promise.

One of the keys to ensuring that IK is preserved for future generations is education. In this paper, the affordances of IK in the school curriculum are explored, as well as the challenges associated with such epistemological border crossing in the classroom.

South Africa is rich in both biodiversity and various IKS. This provides a rich tapestry that could be used to contextualise curriculum themes in the classroom. Sadly, mere lip service is paid to IK in most South African classrooms (De Beer, 2019). Even though the importance of IK is acknowledged in the Curriculum and Assessment Policy Statement (CAPS), the post-colonial school curriculum is still dominated by Western knowledge, values and pedagogies (Ronoh, 2017). IK is mentioned ten (10) times in the current CAPS for Life Sciences. Firstly, IK is mentioned as one of seven principles underpinning the curriculum: "Valuing indigenous knowledge systems: acknowledging the rich history and heritage of this country as important contributors to nurturing the values contained in the Constitution" (Department of Basic Education, 2011: 5). This knowledge system is further highlighted in Specific Aim 3, in terms of exploring the relationship between IK and science (Department of Basic Education, 2011: 13). The curriculum statement also acknowledges the differences between the knowledge systems: "One of the differences between modern science and indigenous knowledge systems is that they have their origins in different world views".

The CAPS for Life Sciences then provides two examples of curriculum content where IK should be explored: (a) the use of traditional medicines, and traditional healers (Department of Basic Education, 2011: 28), and the traditional uses of plants such as devil's claw, rooibos, African potato (*Hypoxis*) and *Hoodia* (Department of Basic Education, 2011: 52).

Da Silva, Pereira and Amorim (2023: 1) make an important observation: "What separates indigenous and western knowledge is not necessarily the knowledge itself, but the underlying worldviews or ontologies and the resulting understanding of what knowledge is and how it is generated". This is also highlighted in the CAPS. This is probably the biggest stumbling block in moving the IK agenda forward. In this paper, this ontological dilemma will be further explored.

RESEARCH METHODOLOGY

This is a theoretical paper exploring ontological perspectives on implementing IK in the science curriculum and classroom. The work was, however, informed by two empirical research projects in which the author was engaged. The first is a National Research Foundation-funded project on the infusion of IK, particularly ethnobotany, in the science classroom. This mixed-methods study explored the affordances of IK in the classroom, as well as the obstacles that teachers face with such border crossing in the classroom. The second project is an ethnobotanical and anthropological study on the medicinal and magic plant use of Khoisan people in the Northern Cape Province, in which the author developed the RIPU heuristic. This was introduced in Indilinga: African Journal of Indigenous Knowledge Systems (De Beer and Van Wyk, 2021) and is further discussed in this paper. This heuristic uses peer-reviewed publications to appraise the rationality of specific plant use (De Beer, 2020).

ONTOLOGICAL CONSIDERATIONS ON THE BORDER-CROSSING BETWEEN NATURAL SCIENCES AND IK

Higgs (2016: 1) made the point that education under colonialism and Apartheid was "hegemonic and disruptive to African practices, Indigenous epistemologies and ways of knowing". The question should be asked whether the acknowledgement of IK in the CAPS addressed this situation. Scholars like Gumbo (2016) advocate for the inclusion of Indigenous perspectives in the curriculum to sensitise learners about the cultural realities in the community. However, research shows that limited reformed teaching practices are seen, and where IK is implemented in curriculum themes, it often boils down to 'lip-service', without learners engaging with ontological matters (De Beer, 2019; De Beer and Kriek, 2021; Petersen, Golightly and Dudu, 2019).

Before engaging with ontological considerations, it is necessary to look at three predominant views on the incorporation of IK in school science curriculum themes. These different perspectives are based on ontology. The first perspective is the so-called inclusive perspective, which views IK as part of science (Taylor and Cameron, 2016; Zinyeka, Onwu and Braun, 2016). Ogunniyi (2004) shows that Western science evolved from the indigenous sciences of the Egyptians, Babylonians, Persians, Indians, and Chinese. This perspective, therefore, advocates the shared tenets between the natural sciences and IK. In contrast, the exclusive perspective views the natural sciences and IK as knowledge systems that are independent. This perspective focuses on the differences in the nature of the knowledge systems, e.g., the natural sciences are limited to the study of the material world, its physical-causal laws, and its empirical, inferential and objective nature (Zinyeka et al., 2016). In contrast, IK is often subjective, holistic, with metaphysical undertones (see Table 1). Sjöström (2007) describes Western science by constructs such as positivism, reductionism and rationalism. In this Cartesian context, humans are seen as "separate from nature" (Zidny et al., 2020:155).

IK, again, is holistic, and humans are seen as living in harmony with nature. It also has metaphysical dimensions. Because of these ontological differences, Onwu and Mosimege (2004) see Western science and IK as two different systems, thus supporting the exclusive perspective. Authors such as Widdowson and Howard (2008) describe IK as 'junk science'. Such authors feel that the inclusion of IK in the science curriculum would distract from developing a true understanding of the nature of science among learners. The third perspective is the 'intersecting domains', in which it is acknowledged that there are ontological and epistemological differences between Western science and IK, but also shared tenets (e.g., both systems are inferential and creative). Advocates for the intersecting domains perspective (e.g., De Beer, 2019) state that learning activities which build on the shared tenets of science and IK should be favoured in the science classroom. One such example would be for learners to investigate the antimicrobial properties of medicinal (muthi) plants by using a Kirby-Bauer technique (De Beer and Whitlock, 2009), as will be explored later in this paper. Such a classroom activity would highlight shared tenets of the two knowledge systems, e.g., their empirical and inferential nature.

Table 1: Ontological and epistemological similarities and differences between natural sciences and IK (based on Cronje, De Beer and Ankiewicz, 2015: 323-324)

Nature of IK	Nature of the Natural Sciences
Empirical and metaphysical The universe is orderly, metaphysical and partly predictable.	**Empirical** Nature is real, observable and testable.
Resilient yet tentative IK has withstood the test of time, but is constantly changing as tradition.	**Tentative** Science is subject to change, based on new experimental findings.
Inferential yet intuitive	**Inferential**

Nature of IK	Nature of the Natural Sciences
Facts are tested, and experimental observations are made. Metaphysical dimensions are important.	There is a clear distinction between observations made from nature and deductions or conclusions (inferences) made from observations to explain the causes.
Creative and mythical Observations and experimenting are not the only tools for knowing; human creativity, imagination, metaphors and myths also play a role.	**Creative** Human creativity and imagination supplement observations and experiments in the creation of knowledge.
Subjective IK is based on cosmology, culture and spirituality, and influenced by beliefs.	**Subjective** Although scientists strive to be objective, as human beings, they are subjective and influenced by prior knowledge and beliefs.
Social, collaborative and cultural IK is situated within a historical-political context, and locally rooted and ecologically based.	**Social and cultural** Scientists attempt to be objective, but science is practised as a human endeavour within a social and cultural milieu.
Wisdom in action New ideas are tested in the 'laboratory of survival'. Solutions to authentic problems are tested through trial and error.	**Rigorous methods** Scientists use a variety of methods to solve problems and test theories.
Functional application IK is applied in the everyday lives of people, a more important focus than theories and laws.	**Theories and laws** A scientific law describes what happens; a scientific theory explains why and how things happen.
Holistic approach Problems are solved in a holistic manner, with no boundaries with the metaphysical world.	**Reductionist approach** Complex phenomena are broken down into smaller parts.

In the next section, possible pedagogies are discussed that could be used within the 'intersecting domains' perspective on IK in the science classroom.

PEDAGOGIES THAT ADDRESS ONTOLOGICAL CONSIDERATIONS WITHIN THE INTERSECTING DOMAINS PERSPECTIVE

It is essential that students understand both the shared tenets of science and IK, and how these knowledge systems differ. There are several classroom investigations explained in the literature that draw on the shared tenets between natural sciences and IK. While engaging in such problem-based and cooperative learning activities, students will learn about IK, using the processes of science. Students would focus on ontological matches between IK and the natural sciences (Western science), e.g. both are empirical and inferential (see Table 1).

The Kirby-Bauer technique for testing antimicrobial activity of muthi (medicinal) plants

With this technique, learners would use microbe-seeded agar plates, in which the chemical substances in the muthi plants would diffuse into the agar medium (Mitchell and Cater, 2000; De Beer and Whitlock, 2009). They will then be able to observe whether the plant contains active ingredients (predominantly alkaloids) which could fight pathogenic infections. This laboratory protocol could be used in even under-resourced classrooms, but it is essential to ensure that non-pathogenic microorganisms are used to ensure the students' safety. A good microorganism to use is *Saccharomyces cerevisiae* (baker's yeast).

Designing experiments to test IK claims

Formulating hypotheses and designing experiments/investigations underpins the syntactical nature of the natural sciences. An example of how students could engage with IK, using the processes of science, is exploring Australian Noongar IK related to seed germination (De Beer, 2012). These native inhabitants of Western Australia treated their crop seeds with smoke to ensure better germination. Karrikins (derived from the Noongar word for smoke, karrik) are butanolide derivatives which result in better seed germination. Learners could (in cooperative learning groups) design and implement experiments to test whether treatment to smoke (experimental seeds) would lead to better germination, compared to the control (De Beer, 2012).

Doing ethnobotanical surveys

Students could engage in a simplified 'rapid ethnobotanical appraisal', where they could record traditional plant- and animal use in their local communities (De Beer and Van Wyk, 2011). The Matrix method (De Beer and Van Wyk, 2011), a rigorous methodology to quantify ethnobotanical knowledge, could easily be used in the science classroom. Flores-Silva, Cuevas-Guzmán and Baptista (2024), in a study in Western Mexico, show that using ethnobotanical knowledge to teach science could better engage learners in the subject content and assist them in conceptual understanding of scientific concepts.

PEDAGOGIES WHICH FOCUS ON ONTOLOGICAL DIFFERENCES

De Beer and Van Wyk (2022) highlight the fact that IK should not be measured or validated using Western scientific knowledge or criteria as the gold standard. The above pedagogies might be criticised for not honouring the holistic nature of IK, by only focusing on the shared tenets with the natural sciences, ignoring the metaphysical aspects thereof. It is therefore essential that learners should also engage with the tenets of IK that are excluded from the above pedagogies.

Two examples of the metaphysical nature of IK are provided below. This serves as context for the Rationality Index of Plant Use (RIPU) heuristic, introduced by De Beer and Van Wyk (2022), which is suggested as a pedagogy that embraces all the tenets of IK. Impinda (*Adenia gummifera*) is a poisonous plant which is traditionally used to sprinkle around the house to inhibit 'evil spirits' (Van Wyk, 2015; De Beer, 2020). At closer investigation of this practice, it becomes clear that it is a similar process to using bleaches and antiseptic products in Western households to inhibit the growth of microorganisms. IK holders realised that Impinda is an effective antiseptic, and for often illiterate IK holders, 'evil spirits' is the terminology used to describe the micro-organisms that cause diseases.

It is, therefore, good science, but poor phrasing. Another 'magic' plant use is the use of Rooivergeet (*Galium tomentosum*) to forget traumatic experiences (De Beer and Van Wyk, 2016). Recent research (Gräff, Joseph, Horn, Samiei, Meng, Seo, Bero, Phan, Wagner, Holson, Xu, Neve, Mach, Haggarty and Tsai, 2014) has identified a histone deacetylase inhibitor in the plant that influences brain physiology related to memory. Nascent research shows that the histone interferes with the process of how brain cells record memories. A possible hypothesis could therefore be that *G. tomentosum* contains active ingredients that affect the physiology of the hippocampus and so influence memory. Such evidence makes the plant's 'magical' use sound more rational.

Cognitively challenging tasks, the RIPU heuristic, and engaging pedagogies

The RIPU heuristic is best utilised within a problem-based and cooperative learning environment, as it could enhance self-directed learning (De Beer, 2019). Using the RIPU heuristic in the classroom poses a challenging task, and therefore, it is necessary to focus on the value of cognitively challenging tasks first.

Cognitively challenging tasks in the science classroom

The role of challenge, especially for high-ability learners, in the learning process is well-researched (Clinkenbeard, 1994; Scager, Akkerman, Pilot and Wubbels, 2012). If the learner is not challenged, he/she might experience boredom, which could lead to a loss of motivation (Scager et al., 2012). The intrinsic motivation theory of Deci and Ryan (1985) states that the learning facilitator should seek a learning task that poses an 'optimum challenge' to sustain intrinsic motivation. However, this asks for caution, as both 'over-challenge' and 'under-challenge' could cause negative emotions. Research shows that when students are challenged, their perceived learning is at its peak. When students experience the challenge level as exceeding their ability level, it often results in increased efforts to master the task. However, the research also shows that the social support of team members is of the utmost importance when dealing with challenging learning tasks.

These insights formed the basis for the development of the pedagogy to engage with the RIPU heuristic. Problem-based and cooperative learning form the pillars of the pedagogy, and research (De Beer, Petersen, Mentz and Balfour, 2022) shows that such approaches could enhance self-directed learning. As a self-directed learner, the student should identify tools to scaffold learning, and ChatGPT (artificial intelligence) could be such a tool.

The RIPU heuristic

The RIPU heuristic requires learners to critically engage with peer-reviewed journals to determine whether a particular use of a plant has a rational basis. This activity is best facilitated within a cooperative learning setting, and the group needs to first determine whether there is a plausible hypothesis underpinning plant use. I will illustrate this in this paper by using the example of *Aloe ferox*. There are many anecdotes amongst different cultural groups on the use of *Aloe ferox* to ward off evil spirits. Learners will discover that 'warding off evil spirits' refers to the plant's antimicrobial and other properties, which hold medicinal benefits (De Beer, 2020).

Learners would do a comprehensive literature search by making use of Google Scholar, the Scopus citation database, and the SciFinder database, amongst others

(De Beer, 2020). This will provide a clear indication of the number of publications, to do the scoring under point 1 in the RIPU heuristic (see Table 2). In groups, learners have to formulate plausible hypotheses for the use of *Aloe ferox* by engaging with literature. Such groupwork should be structured around cooperative learning principles such as positive interdependence, individual accountability and face-to-face promotive interaction, in order to enhance self-directed learning (Johnson, Johnson and Johnson-Holubec, 2008). This is where the complexity comes in, as learners will engage with peer-reviewed journals, interspersed with pharmacological and chemical terms (refer to Table 2). A possible hypothesis might be that this aloe has antimicrobial properties, that could be effective in guarding the body against pathogens (Kambizi, Goosen and Taylor, 2007).

In Table 2, other workable hypotheses are provided, based on the literature. Next, the learners will have to determine what chemical evidence exists that might support the hypothesis. Research into *Aloe ferox* has provided a comprehensive analysis of the active ingredients in the plant and determined that it contains anthrone C-glucoside aloin, also known as barbaloin, which acts as a purgative agent (Goge, Singh, Komoreng and Coopoosamy, 2023). Furthermore, the glycoproteins in the plant provide its wound-healing properties (Van Wyk, Van Oudtshoorn and Gericke, 2002; Goge et al., 2023). (More detail is provided in Table 2). Learners should engage with literature to determine what in-vitro (pre-clinical) and in-vivo (clinical tests in either animals or humans) research has been done to determine the efficacy of *Aloe ferox*. For example (Table 2), research showed that *Aloe ferox* phytosterols in the plant could counteract diabetes (Gherbon, Frandes, Timar and Nicula, 2021). The RIPU heuristic (Table 2) makes provision for giving a score for each category of investigation, and this is then expressed as an index (ranging from 0 to 1), indicating the rationality of its use (De Beer, 2020).

A specific plant use could have a maximum score of 30, which would translate to a Rationality Index of 1.0. This would mean that the use of the plant for a specific reason makes absolute rational sense, based on research data. In contrast, if a plant scores 10/30, it would relate to a Rationality Index of 0.33, indicating that there is a lack of literature supporting a plausible hypothesis and that there might not be significant rationality in its use. In the case of *Aloe ferox*, the high RIPU value of 0.9 (Table 2) indicates that there is a very plausible hypothesis, supported by chemical and pharmaceutical evidence, that indicates that the plant's use is rational. However, while utilising the RIPU, a holistic view on the use of *Aloe ferox* is considered, including the metaphysical aspects. Learners should realise that the use of the plant to 'ward off evil spirits' refers to its wide use as an antimicrobial agent, in order to avoid diseases.

Table 2: Determining the Rationality Index of Plant Use of *Aloe ferox* (Based on the RIPU instrument developed by De Beer, 2020). [A simplified version, for the sake of demonstration]

Item in RIPU heuristic	**Discussion: Measuring the plant use against the criterium**	**Score**
1. Publications 1.1. How many anecdotes were published?	*Aloe ferox* (the bitter aloe or Cape aloe) is an important medicinal plant, and its medicinal uses are well	4

Item in RIPU heuristic	Discussion: Measuring the plant use against the criterium	Score
(None = 0; one or two only = 1; three – 10 = 2; 11 – 20 = 3; more than 21 = 4). 1.2. Was it published in accredited, peer-reviewed publications? (low impact (grey) journals = 1; peer-reviewed journals = 2) 1.3. How many unpublished anecdotes were recorded? (One – 10 = 1; 11- 20 = 2; more than 21 = 3)	documented. It is commercially used as a laxative medicine (Van Wyk et al., 2002; Goge et al., 2023), as well as for the treatment of sexually transmitted infections (Kambizi et al., 2007). The plant is furthermore used for its wound-healing properties (Van Wyk et al., 2002). Other uses of the plant include treating eczema, dermatitis, acne, skin cancer and psoriasis (Goge et al., 2023).	2 3
2. Is there a plausible hypothesis for the plant's use? No = 0 It is possible to speculate = 1 Hypothesis is unpublished (or published in grey literature) = 2 Hypothesis is published in low-impact journals = 3 Hypothesis published in high-quality journals, but there are still unanswered questions = 4 Confirmed hypothesis, published in high-quality journal = 5	There are plausible hypotheses supporting the medicinal use of *Aloe ferox*. The principal purgative agent is barbaloin, an anthrone glucoside aloin (Van Wyk et al., 2002). Glycoproteins are responsible for the plant's wound-healing properties. The plant showed partial activity against the herpes simplex virus (HSV-1), thus demonstrating that it is a good antimicrobial agent (Kambizi et al., 2007). Studies have shown that phytosterols in the plant could counteract diabetes (Gherbon et al., 2021).	5
3. Chemical evidence The chemistry is unknown = 0 Little is known about the chemistry = 1 The chemistry is known, but irrelevant to its use = 1 The chemistry is known and is related to its use = 3 The chemistry is well recorded, and clearly linked to its specific use; there is no doubt of its effectiveness = 5	The chemistry of the plant is well documented. Twenty-one compounds with biological activity were identified in *Aloe ferox* (Goge et al., 2023), with barbaloin, an anthraxcenone, the most important one. Aloeresin is a powerful antioxidant, whereas the resin in the plant promotes anti-ageing effects by restoring UV-damaged cells (Goge et al., 2023).	5

Item in RIPU heuristic	Discussion: Measuring the plant use against the criterium	Score
4. In-vitro evidence for the plant use (pre-clinical tests) No in-vitro tests done = 0 Little or doubtful in-vitro work done = 1 Some in-vitro testing supports the specific plant use = 2 Extensive in-vitro testing, with varied results, indicates limited effectiveness = 3 There is good evidence of rigorous in-vitro testing that supports the plant use = 5	*Aloe ferox* was inoculated onto cell cultures by Kambizi et al. (2007) to study the anti-viral effects of the plant. The authors concluded that the partial activity of the extracts could validate the use of the plant by traditional healers.	4
5. In-vivo evidence for plant use No in-vivo testing done = 0 Some evidence of in-vivo testing in animals = 1 Good evidence of in-vivo testing in animals = 2 Some evidence of in-vivo testing in humans = 3 Sufficient evidence of in-vivo testing in humans, with mixed results, or indicating limited effectiveness = 4 Very good evidence of in-vivo testing in humans, indicating the efficacy of the plant use = 6	A Japanese in-vivo study has shown that the use of *Aloe ferox* could lower and stabilise blood sugar (Gherbon et al., 2021). A study with human patients in India showed that *Aloe ferox* capsules, administered daily, stopped the evolution of type II diabetes. A Romanian study (Gherbon et al., 2021), including an experimental group (n=20) and a control group (n=20), showed that obese participants in the experimental group (who received 3 months of administration of *Aloe ferox*) had lower BMI and cholesterol levels, compared to the (also obese) control group.	4
Total score	A score of 27/30, thus a RIPU of 0.90.	27

The RIPU heuristic, with the associated pedagogy based on problem-based and cooperative learning, provides a cognitively challenging learning opportunity, which spans all the tenets of IK. Learners should realise that both the natural sciences and IK share the characteristic that it is inferential, that facts are tested, and experimental observations are made. However, it should also initiate a debate on whether IK should be validated using Western science methodologies.

CONCLUSION

Unlike the current 'lip-service' paid to IK in the science classroom, e.g., by referring to a few traditional knowledge practices, the pedagogies referred to in this paper, e.g., the RIPU heuristic, follow problem-based approaches in facilitating such epistemological border-crossing in the classroom. Such approaches provide learners with a better understanding of the ontological similarities and differences between the natural sciences and IKS and could contribute to the scientific literacy of students. Such learning tasks scaffold learning about the nature of science and IK, and how such IK could provide innovative solutions to the myriad problems facing humankind. Such pedagogies could also foster self-directed learning.

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