

A Truth-Based Epistemological Framework for Supporting Teachers in Integrating Indigenous Knowledge into Science Teaching

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Integrating indigenous knowledge (IK) into school science teaching is one way of maximising the socio-cultural relevance of science education for enhanced learners' performance. The epistemological differences however between the nature of science (NOS) and nature of indigenous knowledge (NOIK) constitute a major challenge for an inclusive IK-science curriculum integration. This article is about the application of a truth-based epistemological framework designed to support teachers to make decisions on how specific pieces of indigenous knowledge (local traditional practices and technologies) may be included in science lessons. First, an attempt was made to develop a truth-based epistemological framework for identifying epistemology(ies) of indigenous knowledge and practices. Second a group of science teachers used the truth-based epistemological framework to examine ways in which some specified IK practices that comprised a coherent set of knowledge themes on health, agriculture and technology could be integrated into the school science curriculum in a valid and legitimate way. The IK practices used in the study were systematically identified and documented by means of personal observations and interviews of key informants in a rural community in Zimbabwe. The main findings of the study showed that the truth-based epistemological framework was useful in providing an epistemological basis for including some IK practices in science teaching and learning. As a tool for pedagogy the framework enabled the science teachers to reconsider and change their valuing of Indigenous knowledge Systems (IKS), more specifically in ways in which local knowledge can validly be incorporated into school science teaching.

Keywords: *Truth-based epistemological framework; indigenous knowledge; inclusion of IK in science*

Introduction

The inclusion of indigenous knowledge (IK) in the curricula is an important component of contemporary science education in many countries (e.g. Department of Education, 2002, 2005; Ministry of Health and Child Welfare, 2007). Political, utility and pedagogical reasons have been cited as major reasons for the valuing of, and growing interest in, integrating Indigenous Knowledge Systems (IKS) into science curricula (Webb, 2011). Arguments that are premised on pedagogical considerations for instance, include the observation by Webb (2011) that at times non-western learners opt out of school science because of the apparent alienation caused by the clashes between aspects of their cultural universe which they are accustomed to and those of the scientific worldview. There is also the

recognition that there are epistemological differences between the two knowledge systems, which pose serious challenges for any attempts at inclusion and integration.

In a recent article, Taylor and Cameron (2016) clearly highlight and critique three epistemological related perspectives that are inherent in the attempts at IK-Science integration. The different perspectives are worthy of further analysis to see the extent to which they can provide a platform or some form of heuristic for the inclusion of IK in science teaching. Specifically, the authors put forward the proposition that on the one hand there is the inclusive perspective where IK systems are regarded as part of science, and on the other hand there is the exclusive perspective in which IKS and science are treated as separate domains of knowledge. The exclusive scientific perspective has been that science is limited to studying the material world only and has nothing to say about the supernatural. IK systems however acknowledge the possibility of the supernatural in their domain. The authors suggest a third perspective where IKS and science are viewed as intersecting domains, of overlapping strands. This third perspective where science and IKS might be considered to potentially overlap provides a conceptual basis for making a distinction between specific 'pieces of indigenous knowledge' that intersect with modern science knowledge and its ways of knowing, and the other unique systems of indigenous knowledge as ways of knowing with distinctive worldviews. Such a distinction offers the promise of a valid pedagogical approach to the inclusion of aspects or pieces of indigenous knowledge in science classroom practice. With this in mind, it was considered necessary to attempt to incorporate IK into science teaching by proposing a truth-based epistemological framework for identifying specific pieces of IK suitable for inclusion in science classroom teaching in a valid and legitimate way. Hence the purpose of this article is to develop some heuristics to assist science teachers in including IK in their science lessons by using a truth-based epistemological framework.

Epistemological Differences between IK and Science

Given the epistemological differences between IK and school science, it is necessary to briefly examine the respective natures of the two knowledge systems. There is no one definition of IK that could be construed as all embracing. In this study IK is broadly viewed as knowledge gained by systematically observing nature and by trial and error experiments as defined by Onwu and Mosimege (2004). IK is manifested in practices and is transmitted orally, and at times through imitation, demonstration, paintings, writing, and other artefacts (Kibirige & Van Rooyen, 2007). According to Onwu and Mosimege (2004, p. 2), 'Indigenous Knowledge is an all-inclusive knowledge that covers technologies and practices that have been and are still used by indigenous and local people for existence, survival and adaptation in a variety of environments'. Such knowledge covers areas such as agriculture, architecture, engineering, mathematics, medicinal and indigenous plant varieties, governance and other social systems. It is cumulative and evolving knowledge, based on experience. It privileges the community to validate it over many generations based on using the knowledge (Ogunniyi, 2013), together with aspects of spirituality and philosophy (Rich, 2012). This all-encompassing definition of IK presents both ontological and epistemological propositions about its nature. Thus IK embraces both testable and non-testable metaphysical phenomena, as it tries to understand systems as wholes and as its spiritual component is deeply embedded in indigenous ways of knowing.

Science on the other hand, according to Ogunniyi (2011, p. 102), is 'concerned with testable phenomena' and considers the universe as knowable. McDonald (2013, p. 2) posits that 'the epistemology of science can be viewed as the logical and philosophical grounds upon which scientific claims are proposed and justified'. Sandoval (2005) further argues that the epistemology of science encompasses not only the sources of scientific knowledge and the values used to justify that knowledge, but also the ways of knowing used by the scientific community to accept scientific knowledge. Thus, for the science teacher the most important difference between the two knowledge systems is that IK systems accept aspects of the universe as mysterious, their sources and ways of knowing embrace spirituality, whereas modern or orthodox science and its useful methods and ways of knowing does away with the notion of spirituality and instead sees the universe as being knowable. The qualitative differences between the two knowledge systems do not necessarily imply a disjunction or incompatibility

between IK and school science. As described by Juttner, Boone, Park, and Neuhaus (2013) there are elements on which both systems agree, and in this way some aspects of the two knowledge domains intersect (Taylor & Cameron, 2016). These dimensions of knowledge (Juttner et al., 2013) include declarative or propositional knowledge ('knowing-it' for providing factual knowledge) and procedural knowledge ('knowing-how' for providing evidence of practical knowledge). However, IK and science typically do not converge on a further dimension, i.e. conditional knowledge or 'knowing the how and why', which is knowledge that is explanatory and used to justify and establish a sound basis of support for beliefs, decisions and/or actions. In essence explanatory knowledge is truth-based and logical, and is accommodated in science only. Precisely for this reason, in science teaching, knowledge of content is not only to know that something is so; the teacher must further explain why it is so. For IKS, however, the spiritual is sometimes included in explanations; which is incompatible with the scientific way of knowing. Hence, only the pieces of IK in the intersection between science and IKS, what Taylor and Cameron (2016) call the third perspective, could arguably be included in science teaching or lessons because they overlap with science. On the basis of those assumptions and perspectives we sought to develop a truth-based epistemological framework for identifying pieces of IK practices for inclusion in science teaching.

The Study

Most secondary school science curriculum statements fail to specify how to include IK in the school science curriculum, and for this reason among others, science teachers have different perspectives and interpretations of how best this inclusion can be achieved (Onwu, 2012). A truth-based epistemological framework for identifying IK practices that are compatible with school science, has the potential to spawn other intrinsic interests among science teachers including changing their views about the value of integrating local knowledge into science teaching. This study therefore sought to address the following questions:

How can existing frameworks for integrating knowledge systems be used to develop the truth-based epistemological framework for including IK in school science teaching in a valid and legitimate way?

In their application of the truth-based epistemological framework, what do teachers think about the basis upon which the identified IK practices may be included in school science teaching?

How did teachers' views shift as a result of their familiarisation with and use of the truth-based epistemological framework?

Frameworks for Integration

Some knowledge integration frameworks are summarised below with the aim of assessing how useful they could be for resolving the challenges of including IK in school science teaching. Within the scientific and science education community there is a general agreement that the processes of science and its useful methods, values and ways of knowing and the ontological characteristics of the resultant scientific knowledge are robust and stable enough to clearly demarcate science from other ways of knowing such as IKS (Lederman, Lederman, & Antink, 2013; Webb, 2011). Without those characteristic features of science which is about the demand for truth and adequate justification (Horsthemke, 2004) other ways of knowing may have no place in the science curriculum as scientific knowledge, but may have a position as an area perhaps for debate (Onwu & Mosimege, 2004; Vhurumuku & Mokeleche, 2009) and/or as complementary knowledge (Onwu & Mosimege, 2004; Taylor & Cameron 2016). The question then arises: *What criteria must other ways of knowing meet in order to be considered within the purview of science and its curricula?*

In an effort to resolve the epistemological challenges one of the integration frameworks that was reviewed was that of Loubser (2013), concerning the relationship between pre-scientific and scientific frameworks. Loubser (2013) argues that 'pre-theoretical' systems, which are viewed as analogous to pre-scientific framework, are usually the starting point in science which then develop into 'theoretical'

systems notably the more elegant scientific frameworks. In equating 'scientific' with 'theoretical' knowledge he suggests that understanding the background of 'theoretical' systems, together with the true epistemological differences and similarities between 'theoretical' and 'pre-theoretical' knowledge, could provide some insight into the interrelations between the two frameworks, ('scientific' and 'pre-scientific') and possibly explain 'how they could cohere with one another', with regard to knowledge integration (Loubser, 2013, p. 81). The two types of epistemic frameworks include on the one hand scientific knowledge which is 'theoretical' and is produced through a process of abstraction and the scientific way of thinking, which emphasises observation, experimentation and universal principles of description, explanation and prediction (Sankey, 2008). On the other hand, local knowledge such as IK is said to belong more to the 'pre-scientific' class of knowledge. This class of knowledge is usually considered to be forms of knowledge that are experiential, holistic, community based (whilst being simultaneously held very subjectively), and traditionally transmitted (rather than through formal study) (Kibirige & Van Rooyen, 2007). The beliefs comprising these systems are usually held on religious, worldview, cultural and community level bases and assist the community in meaning-making whilst also providing normative direction (O'Donoghue, 2010).

While it may be true that the awareness of the relationship between pre-scientific and scientific knowledge systems could be useful in explaining that 'worldviews are recognised frameworks in scientific thinking' (Loubser, 2013, p. 80), it is difficult to see how this understanding is able to help the science teacher handle characteristic features of other worldviews, which do not fit into the nature of science.

The second integration framework reviewed was that which sets precision, universality and falsifiability as requirements for good scientific theories. Following Popperian thinking, Cohen, Manion, and Morrison (2011, p. 10) state that 'a theory should demonstrate precision and universality, and set the grounds for its own falsification'. The framework implicitly accepts the epistemological criteria of scientific knowledge as a measure upon which indigenous knowledge (and other ways of knowing) could be judged. However, the challenge teachers may face when using this framework is that while teachers could map knowledge using falsification, their training does not always include philosophical aspects of science such as falsification and justification which might be very involving. Additionally, this framework does not provide teachers with the procedural knowledge of how to demarcate IK for purposes of determining suitable teaching strategies for including IK into their science teaching.

The third integration framework that was considered was that of Webb (2011), which is primarily concerned with demarcating science while trying to bridge the gap between science and indigenous knowledge systems. Webb (2011) suggests that by combining Loubser's (2013) framework on how knowledge develops with Popper's requirements for demarcating bad from good theories it becomes possible to map where different knowledge claims should fit. Webb's (2011) distinction between pre-theoretical and theoretical knowledge is similar to Loubser's pre-scientific and scientific frameworks and furthermore, his falsifiability distinction is in synch with Popper's falsification requirement for good theories. Although Webb's framework of combining both Loubser's and Popper's work makes it possible to map where different knowledge claims should lie, it does not provide the teachers with the tool for determining the reasons why that is the case.

Given some of these objections, it was found necessary to explore the possibilities of using theories of truth as the logical grounds to establish a set of criteria that other ways of knowing may be expected to meet in order to be considered compatible with school science curricula.

Theories of Truth as a Conceptual Framework

The conceptual framework of the study was the truth-based epistemological framework developed for identifying epistemologies of IK practices. Bernecker and Pritchard (2011) describe epistemology as that part of philosophy that deals with knowledge for interrogating the notions of truth, beliefs and perceptions. Knowledge is justified true belief, and epistemology is concerned with the grounds for accepting such beliefs (e.g. statement, sentence, proposition, etc.) about the world as true (Bernecker & Pritchard, 2011). There is no consensus among philosophers about what truth is and this concept

has been defined in a variety of ways. In this article, the correspondence, pragmatic and coherence theories of truth commonly regarded to be the traditional and substantive ones (Bernecker & Pritchard, 2011) are considered. These three theories form the basis upon which knowledge claims are interrogated and are accepted in many contexts (Audi, 1995).

The correspondence theory, posits that a knowledge claim or a belief is true provided there exists a fact (empirical basis) corresponding to it (Audi, 1995; Lynch, 2011). It however fails to account for all forms of reality such as moral and mathematical propositions and therefore may not necessarily be construed as a universal theory of the underlying nature of truth (Lynch, 2011).

The pragmatic theory views truth in terms of what would solve a problem. Thus, truth is seen in terms of its practical bearing on human interests and events (Audi, 1995).

Lastly the coherence theory offers the argument that a belief is taken as true when it is part of an entire system of accepted beliefs and knowledge that is consistent and 'harmonious' (Audi, 1995). When a belief fits well with already accepted systems of beliefs it is accepted as true. The coherence theory of truth, could be an opening for inclusion of 'mysterious' aspects of IKS in science lessons.

The above theories of truth comprised the elements of the conceptual framework for the study. The framework (see Figure 1) was intended to support teachers to make decisions on how specific pieces of indigenous knowledge may be included in science lessons.

The application of the framework in Figure 1 in this study is shown in the method section as presented below.

Method

The study consisted of two phases: the first phase was the development of the truth-based epistemological framework. Its content validity was established using three university philosophy of science lecturers.

In the second phase, two high schools were randomly selected from seven schools in the Chikwanda area in Zimbabwe offering science, mathematics and technology subjects from Form 1 up to Form 4 (Grades 9 to 12). Each of the schools had six qualified and experienced science teachers. The 12 science teachers who were from the local community and Shona-speaking themselves volunteered to participate in the study. Their culture is the same as that of the community from where the IK practices used in the study originated. Six documented IK practices and technologies were made available to the science teachers during a two-day workshop that was aimed at equipping them with the skills of logic and argument for analysing the IK practices within the elements of the truth-based epistemological framework to determine aspects of the practices that can be said to intersect (or not) with scientific ways of knowing.

A selection of IK practices (see below) which formed part of a coherent set of knowledge themes on health, agriculture and technology in a Zimbabwean community was identified and documented by the researchers, one of whom is Shona-speaking as is the community participating in the study. The

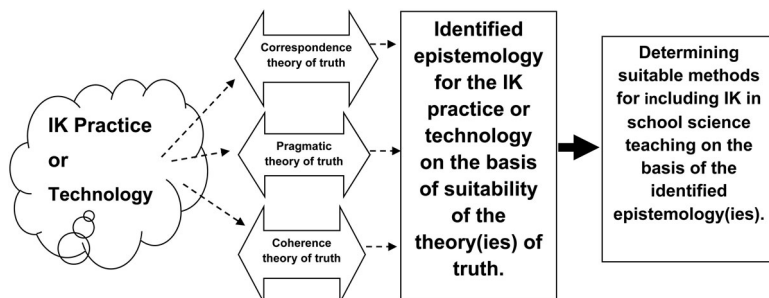


Figure 1. Framework for identifying epistemologies for IK practices and technologies on the basis of three theories of truth

selection was done by means of personal observations and interviews with key informants over an extended period. The characteristic features of the six practices were carefully described and analysed using the truth-based epistemological framework. The aim was to establish which aspects were compatible with science (IK-science overlap) and which were not (Dube & Lubben, 2011).

Description of IK Practices Used in the Study

The six descriptions below present representative voices of the respective IK practitioners who were observed and interviewed as key informants over an extended period. The transcribed protocols involved back-translation from Shona to English and back to Shona. Practitioners are referred to by number (P1 to P21).

Cereal Seed Preservation Method

P1. During harvest time, which is usually in April and May, we select a variety of seed crops such as maize, millet and sorghum. We exchange crop seeds with our relatives and neighbours to get better and higher yields. We have observed that using the seed produced from the same crop over many seasons makes the crops weak. We select and store in our traditional kitchen sufficient and suitable crop seeds for planting in the next season. We do not shell the maize, millet and sorghum seed from the stock so as to make it easy for us to hang them inside the thatched kitchen. As we make fire every day for cooking, the smoke gets to the seeds and black soot covers them over time. The kitchen temperature is generally high and sufficient for hardening the hanging seeds. We have realised that pests do not attack seeds with soot. Over many generations, our people have used this method which we refer to as '*kudzivirira zvipfuto*' – translated as preserving the seed crops from being attacked by weevils. This practice is called '*Kuchengetedza mbeu muchitsi mumba yokubikira*' in our language – 'preserving the seed crops using carbon soot from firewood smoke'.

Treatment of Abdominal Diseases using the '*Munhunguru*' Tree (Botanical Name: *Flacourtia indica*)

P17. In this community, if a person is suffering from abdominal pain, tummy ache or diarrhoea and he or she is unable to walk on his or her own, helpers generally carry the patient to the bush. The patient is lifted up and assisted to pluck two to three leaves of the '*munhunguru*' tree with their mouth, like a giraffe, without touching the leaves of the tree. The medicine is supposed to work only when the patient takes the prescribed number of leaves with the mouth without touching the leaves. I think that our elders might have included this requirement after realising that this resource, the '*munhunguru*' tree, might be depleted if nothing is done. The poor health of people living in the rural community mainly from waterborne diseases and communicable diseases could easily lead to environmental degradation, with many people wanting to use the '*munhunguru*' tree for treating the ailments. So the plucking of the leaves using the mouth is a deliberate strategy I think designed to ensure that the tree is not overly used. The patient chews about three leaves of the '*munhunguru*' tree and swallows the juice and they get healed. It has been experienced over time that the quantity of leaves has to do with the amount of juice that comes out of them. Three leaves produce juice just sufficient for treatment without causing harm to patients and trees.

Treatment of Abdominal Pain using *Chimuwatonzvi* (*Dicoma anomala*)

P21. We use *chimuwatonzvi* to treat abdominal pain. To treat abdominal pain, we crush one to two tubers of the *chimuwatonzvi* and mix it with a cup of water. Half a cup of the mixture is then given to the patient to drink three to four times a day. Normally a person is healed within three days of starting treatment.

Making a Fire

P9. Our forefathers used to start fire from the friction of two bone-dry pieces of *mukubvu* tree (*Vitex payos*). First, they would make a hole halfway into a thick piece (log) of dried *mukubvu* tree. They would then make a metre-long spindle cut from a dry piece of *mukubvu* tree and sharpen one end. The sharp end of the spindle was then placed into the prepared hole of the *mukubvu* log. Several people in turn would roll the spindle by running it very fast between their palms to produce a temperature hot enough to have an ember to start glowing.

Local Fertiliser

P5. We use *mupfudze* (cow dung) from our cattle kraals to fertilise crops such as maize. Over time our ancestors observed the healthy growth of grass around the cattle kraals and attributed it to cow dung. It was through keen observation of their surroundings that they came to associate cow dung with healthy plant or grass growth, especially in the rainy season. Almost everyone in this community uses cow dung from the cattle kraal as fertiliser for growing their crops.

Roof Thatching

P13. We use dry grass, dry poles and ropes obtained from the inner side of the barks of trees such as the *mutondo* tree (*Julbernardia globiflora*) to roof our huts and houses. Skilled artisans first fix about four or five wooden poles, in such a way that they all meet at one point (i.e. the apex of the roof under construction) in the middle of the hut. After fixing the apex of the roof, we then position several wooden poles cut to the required length on which the dry grass [thatch] will be attached using the sisal ropes. We then sew the thatch on the poles layer by layer working from the bottom to the top of the roof using dry grass and ropes.

During focus-group discussions the 12 teachers were requested to analyse and classify the above selected IK practices using the truth-based epistemological framework to determine theory/ies upon which aspects of the selected practices can be said to intersect (or not) with scientific ways of knowing and to give reasons for their answers. The teachers' views were also sought on the usefulness and efficacy of the truth-based epistemological framework and the impact, if any, its application has had on their views about including IK in school science teaching.

The discussions were video-recorded and later transcribed verbatim to obtain accurate and comprehensive records of the conversations. Data were described checking for similarities, coherence and consistency. All data/quotations presented in the results section are transcriptions of the teachers' speech.

Results and Discussion

Teachers' Views about the Basis upon which the Identified IK Practices may be Included and Integrated into School Science Teaching

Table 1 displays a summary of the outcome of the teachers' explanations on theory/ies upon which aspects of the selected practices can be said or not to intersect with scientific ways of knowing. The representative teachers' voices for each theory of truth in relation to each of those six practices are included in the table. Teachers are referred to by number (T1 to T12).

The teachers' explanations for the suitability of the inclusion of the practices in science teaching could be summarised as follows: most practices are considered by the teachers to have aspects fitting both the correspondence and the pragmatic theories. Specifically, the teachers noted that five of the six practices are practically done (with the exception of abdominal pains and diarrhoea treatment using the '*munhunguru*' tree), and their procedures can be observed and are repeatable producing similar or identical results (the correspondence theory) which should allow for incorporation into their science teaching. The explanations include aspects of knowing it, knowing how and knowing why-offering justifiable explanation. This would appear to confirm the argument that some aspects of the two knowledge domains can intersect (Ogunniyi, 2013; Taylor & Cameron, 2016) and that this could provide opportunities for active learning in classroom science (Kibirige & van Rooyen, 2007).

The teachers also felt that all the six practices could partly be explained in terms of their pragmatic value to the community (Table 1) since the practices have proven to solve real problems in their lives. None of the teachers pointed towards the coherence theory for any of the practices.

All 12 teachers involved in this study were of the view that the framework was useful for identifying pieces of IK for the purposes of supporting them to make decisions on how they may be included in science lessons. It could be argued that the truth-based epistemological framework provides teachers with a tool for making decisions on how specific pieces of IK may be included in science lessons which could be a solution to challenges faced by the use of Webb's (2011) framework.

Table 1. Teachers' explanation for the IK classification using the truth-based epistemological framework for the six identified IK practices

IK practices/beliefs	Correspondence theory of truth	Pragmatic theory of truth	Coherence theory of truth
Cereal seed preservation method for a variety of seed crops using sooth.	T12: <i>'Since every stage in the practice can be observed and done practically, reality is grounded on empirical evidence.'</i> T8, T2 and T4 pronounced the same opinion and the other teachers agreed.	T10: <i>'Cereal seed preservation method has been used by these people over many generations and is practiced because it solves a problem.'</i> This was a representative statement by all the other teachers	This theory was not referred to by all teachers.
Abdominal pains and diarrhoea treatment (AP and DT) using a specific number of leaves from the 'munhunguru' tree (<i>Flacourtia indica</i>).	None of the teachers made any overt reference to the correspondence theory of truth in their explanation of whether the practice has aspects with empirical evidence that could be said to intersect with scientific ways of knowing.	T8: <i>'Since the medicine only works when the patient takes the leaves without touching the leaves, the spiritual element makes it difficult to know why the medicine works.'</i> Eleven teachers had similar explanations but T9 had reservations.	None of the teachers made reference to the coherence theory.
Abdominal pain treatment method using <i>Dicoma anomala</i>	T7: <i>'The treatment involves practical steps that are observable.'</i> The other teachers had similar explanation.	T10 and T2: <i>'These people have used this treatment and have found it working.'</i> The teachers agreed.	This theory was not referred to by all teachers.
Technology using the mukubvu tree (<i>Vitex payos</i>) to make a fire.	T9 and T6: <i>'There is empirical evidence from the materials they use to make fire.'</i> The other teachers agreed.	T1: <i>'The method works'</i> . The other teachers agreed.	This theory was not referred to by all teachers.
Indigenous method for fertilising crops such as maize using <i>mupfudze</i> (cow dung)	T10: <i>'It could be argued that this practice intersects with science because whole procedure is observable.'</i>	T11: <i>'The method's practical use and positive results show that this practice has an element of pragmatic theory of truth.'</i>	This theory was not referred to by all teachers.
Traditional roof-making technology	T12: <i>'They roof their huts and houses using this method, all the steps of the process of construction can be observed.'</i>	T11: <i>'The traditional roof making is useful with respect to their interests.'</i>	This theory was not referred to by all teachers.

The teachers' observation about the abdominal diseases treatment using the 'munhunguru' tree was that the unusual requirement of plucking the leaves using the mouth was introduced to foster specific kinds of behaviour. The need to know how and why the local herbal medicine works could provide a singular educational opportunity for the teacher to use profitably on the learners' behalf. As argued by Vhurumuku and Mokeleche (2009, p. 98) this aspect of IK therefore, has no place in the 'school [science] curriculum as knowledge, but may have a place as an area for debate' and with value for society.

Teachers' Views about the Inclusion of IK Practices in Science Teaching Curriculum

Lastly, the question regarding teachers' post-activity views about IK inclusion in science teaching yielded several responses which could be categorised into themes. Three themes emerged from their narratives.

First, about 25% of the teachers expressed opinions which could be construed as paradigm shifts, from an initial mindset of preferring total exclusion of IK practices in science education to a willingness to include in their science lessons where appropriate those aspects of IK which have a scientific base. They moved from thinking that all IK is 'superstition ridden' to realising that there are IK practices and beliefs that are practised on the basis of logically sound and valid reasons. These sentiments are as expressed by teacher T6:

I used to think that all IK is primitive and superstition-dominated and not to be included in science. I now hold the view that there are many IK practices that are based on reasons that can be identified using this framework. Most of the practices we have studied here have empirical evidence. I now believe that it is of beneficial effort to teach science including some aspects of IK into it.

Other teachers (17%) argued for the total exclusion of IK practices that lack empirical evidence especially those that contain elements that are inadmissible in science, notably, spiritual aspects. T1 for example, in agreement with T12, insists that:

I don't think science should entertain IK practices and beliefs that have no empirical evidence and those with spiritual elements. They have no room in science because science is about facts, laws and theories that require empirical evidence.

It is worth noting that teachers in the first and second groups clearly wish to include only 'pieces of IK' where evidence can be identified, and exclude the IK practices based on spiritual arguments. Both groups of teachers are arguing in ways that are consistent with the gate keeping device of orthodox science and in accord with Taylor and Cameron's (2016) third perspective.

Lastly, the remainder (58%) of the teachers support the idea of including aspects of IK that may be non-scientific in their science teaching but suggest that the epistemology(ies) of such local knowledge be interrogated or rationalised, and that the purpose for their inclusion be justified and made clear or explicit. These teachers still view demarcation as necessary in line with Vhurumuku and Mokeleche's (2009) argument. For instance, T11's view is representative of this majority third theme as follows:

Total exclusion of some components of IK practices when integrating it with science is likely to result in losing the opportunity to harness the holistic value of IK in the teaching and learning process. We should include in the teaching and learning of science aspects of IK inclusive of those with spiritual components. Some aspects may have no place in the school science curriculum as scientific knowledge, but for purposes of deliberation (discussion) they should be included at the same time showing the rationale or reason for including it. Perhaps with some of these practices learners could benefit from laboratory testing and investigation, testing or exploring indigenous ways of doing research, involving learner argument and personal contribution. Especially the discussions will be to reinforce the idea that science may not always have all the answers—it is tentative.

Teachers' Recommendations of Suitable Teaching Methods

Teachers suggested some subject matter content and methods for incorporating various IK practices including the one of cereal seed preservation, as elaborated by T3:

Experiments, observations and practicals can be used to teach those practices with empirical evidence such as cereal seed preservation. For example, in agriculture, under the topic pests and diseases control, seeds can be placed in different places, some in a place where there is supply of smoke everyday and some in a place where there is no smoke supply. Having subjected seeds to these different conditions, observation can be done over five or more months to see what happens.

The results and major findings of this study demonstrated that a truth-based epistemological framework was useful in identifying pieces of IK practices that could be included in science teaching. Although teachers initially expressed scepticism about integrating IK practices into school science, their familiarisation with the framework enabled them to review their position about valuing IK.

Conclusion

The main findings of this study altogether provide a conclusion that the epistemology of IK practices can be accessed by science teachers themselves for supporting their pedagogy. Aspects of IK practices can be analysed using the truth-based epistemological framework. In addition, the findings show that teachers are able to identify appropriate points at which aspects of IK can be included in the science curriculum.

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