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Towards culturally relevant classroom science: a theoretical framework focusing on traditional plant healing

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Abstract A theoretical framework is an important component of a research study. It grounds the study and guides the methodological design. It also forms a reference point for the interpretation of the research findings. This paper conceptually examines the process of constructing a multi-focal theoretical lens for guiding studies that aim to accommodate local culture in science classrooms. A multi-focal approach is adopted because the integration of indigenous knowledge and modern classroom science is complex. The central argument in this paper is that a multi-focal lens accommodates the multifaceted nature of integrating indigenous knowledge and western oriented classroom science. The objective of the paper, therefore, is to construct a theoretical framework that can be used to guide and inform the integration of indigenous knowledge and western science at classroom science level. The traditional plant healing form of indigenous knowledge is used as a case study. The paper is important for raising the complexities, tensions and dilemmas inherent in the design and implementation of indigenous knowledge-science integrated curricula. An understanding of the issues raised will pave the way towards achieving culturally relevant classroom science.

Keywords Classroom science · Indigenous knowledge · Integration · Theoretical framework · Western science

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Many science education stakeholders now acknowledge the interaction between culture and classroom science. These stakeholders, such as parents, science teachers, ministry officials and researchers, share Gloria Snively and John Corgsilia's view of science as existing in every culture (2001). According to Edward Shizha (2006) each culture has its own unique science. This is in agreement with Xenia Meyer and Barbara Crawford's view of science as a cultural way of knowing (2011). This view places science within a multicultural frame of reference which accommodates diverse cultures in the world. In this sense, as posited by Glen Aikenhead (1996), western science is a sub-culture of the western culture that signifies one form of science among many 'others' (Ogawa 1995). The 'other' here entails science knowledge that is native to the culture of a specific group of people of a particular locale or region or land (Odora-Hoppers 2002). The "other" excludes western culture and includes indigenous knowledge. Indigenous Knowledge is commonly referred to as indigenous knowledge systems (IKS).

The term indigenous is used to refer to the cultural roots of something (Odora-Hoppers 2002). In this paper, the term 'something' refers to knowledge, described in literature as either indigenous knowledge or IKS (IK/S). As Loubser (2005) notes knowledge that is indigenous is linked to native locales of origin. IK/S are holistic in nature, meaning, as Ray Barnhardt and Angayuqaq Oscar Kawagley note, they are not compartmentalised or divided up into subjects as in the Western knowledge system (2005). Instead sub-divisions of knowledge, such as agriculture, law, medicine, religion, spirituality, including values in the Western sense, are interwoven into a sum total way of living tied to the Land of origin (Battiste 2002; Kawagley 1995). For example, the Karanga people's way of managing health is a form of cultural knowledge which is part and parcel of this tribe found in the Masvingo region of Zimbabwe, in Africa. Though in literature most authors use the terms IKS and indigenous knowledge interchangeably, we relate but make a distinction in our use of them. We adopt Otulaja, Cameron and Masimanga's (2011)) proposition of IKS as the foundations from which the indigenous knowledge has to come. It is from indigenous knowledge that what would be integrated with modern classroom science can be selected.

In literature, not only are the definitions of indigenous knowledge varied, but that of IKS as well. Warren and Rajasekaran (1993) define indigenous knowledge as local knowledge unique to a given culture which has been acquired through the accumulation of experiences, informal experiments, and intimate understanding of the local environment. In Nakashima's (2000) view, indigenous knowledge refers to a complete body of knowledge, know-how and practices maintained and developed by people through interaction with the natural environment. In this paper we adopt Nakashima's definition as we recognise its direct link to IKS in its definition provided by Vhurumuku and Mokeleche (2009). These authors refer to indigenous knowledge as a set of understanding, interpretations and meanings of the world grounded in IKS. They define IKS as a complex cultural matrix, which Ogunniyi (2007) unpacks as a conglomeration of knowledge systems encompassing science, technology, religion, language, philosophy, politics, and other socio-economic systems. To this definition Mack, Augare, Cloud-Jones, Davı′d, and Gaddie (2012) add the spiritual component.

In science education, researchers such as Aikenhead (1996), Cobern (2000) and Ogunniyi (2004) have long recognised cultural differences between the Western and indigenous cultures which are often conflicting. Today western science-oriented classroom science, which we here refer to as modern classroom science, is on offer in schools in many parts of the world (Guo 2007), a status quo with many links to colonial history. Classroom science here simply describes the teaching and learning of science within the context of schooling. It entails what is to be taught (content), how it is to be taught (pedagogy) and why it is taught (purpose or goals). Many years ago, colonialism created cultural imbalances not only in science education but also in many other systems and disciplines by upholding western cultural ways of knowing and subjugating IK/S (Shizha 2006, 2010). To date these imbalances are overtly reflected in African schools, particularly in science classrooms, substantiating African science education stakeholders' (e.g. Makhurane 2000) criticism of modern classroom science as failing to accommodate African cultures.

The integration of IK/S with modern classroom science has become a popular strategy for aligning the later with indigenous cultures in many nations. This has come to be a strategy regarded as a cultural relevance corrective measure that indigenises modern classroom science. Many tags have been attached to attempts to indigenise school science. Such tags include cross-cultural (e.g. Aikenhead 2000), multi-cultural (e.g. Cobern and Loving 2001), cultural-sensitive (Jegede and Aikenhead 1999), and culturally responsive science education (Brayboy and Castagano 2008), among others. In this paper, we use the term culturally-aligning classroom science (CACS) for all these different tags.

The research context in brief

In science education culture-relevancy reform movements can be traced as far back as the past three decades in some parts of the world. For example, in 1984 George Guilmet reported on a research strategy to develop science curricula to accommodate diverse cultures of American Indian and Alaska Native children. At almost the same time, Meshack Ogunniyi (1988), an African scholar, put forward the need for science education to adapt western science to traditional African cultures. To date, in many nations, the call for integration of IK/S into modern classroom science has become one of the topical strategies for redressing cultural imbalances in the science classrooms (Brayboy and Castagano 2008). In actual fact, as noted by Ogunniyi, efforts to integrate IK/S into modern classroom science are underway in many Western nations of Australia, Canada, New Zealand, and the United States of America (2007). In like manner, in Southern Africa, Zimbabwe and South Africa are engaged at different levels of integrating indigenous knowledge into modern classroom science.

Though contested, there are strong points for the argument that Western science was one of the many tools used for colonisation (see Suman Seth 2009). As a colonial tool, western science was intentionally used to diminish IK/S, by so doing spearheading the superiority of western ways of knowing and domination or, as literature describes it, colonial hegemony. In these former colonies, such as Zimbabwe, the colonial hegemonic state of western science over IK/S remained a legacy well into their independence (Shizha 2006). To date, the western science domination over IK/S is overtly reflected in many science-related systems, such as agriculture, health and science education. In science education, stakeholders acknowledge that currently science curricula, which is modern classroom science, on offer in schools worldwide are largely Western scientific culture based (Aikenhead 1996). It is against this background that Africa former colonies and other nations in similar contexts are involved in movements to decolonise themselves. As part of this decolonising movement, the IK/S-science curricula reforms goals in African ex-colonies revolve around the ideology of countering colonially-inflicted Western domination and redressing imbalances (Vhurumuku, Holtman, Mikalsen and Koltso 2008).

Worldviews, which are culturally dependent, influence fundamental organisation of the mind. This phenomenon presumes and predisposes one to feel, think and act in a predictable manner (Cobern 2000). Worldviews form one's set of culturally grounded assumptions and beliefs about the nature of the world (Nyawaranda 1998). So, when the learner's worldview is different from that of modern classroom science culture the former becomes foreign to the later. This largely explains why the majority of learners worldwide, irrespective of their cultural backgrounds, often find the learning of modern classroom science problematic. Ogawa (1995), Ogunniyi (1988) and Jegede (1996) and many others have written much about the problematic aspects of learning modern classroom science by African learners.

Worldviews held by learners are also considered to be strong (de) motivators to learning science (Cobern 2000). They also influence an understanding of it (Hewson et al. 2009). As Terry Lyons (2006) notes, the decline in upper high school science enrolments and beyond in many parts of the world can, to a greater extent, be attributable to diminishing interests in modern classroom science due to its foreignness to the learners.

Maureen Klos suggests culturally adapting school science to make its learning interesting and relevant to learners, particularly those with an indigenous cultural background (2006). It is against this background that we underpin our theorisation of CACS on the major assumptions that it has a high chance of enhancing cultural relevance of modern classroom science for all learners. By so doing, we regard CACS as a possible tool for addressing problems emanating from worldview interactions in the learning of science. In addition, the CACS as a process can be regarded as a vehicle for boosting the dwindling enrolment of the upper secondary science classes in many communities.

In this paper, we adopt a cultural perspective to science education that provides us with insights into worldview interactions in relation to teaching–learning. Within this frame of reference, stakeholders in science education need to recognise and acknowledge: (1) science as basically knowledge existing in every culture (Snively and Corgsilia 2001) (2) Western science as sub-culture of the Western culture (Aikenhead 1996) (3) science as a cultural entity in itself (Jegede and Aikenhead 1999) (4) MCS as select from the scientific culture in view of Denis Lawton's assertion of curriculum as a selection from culture (1978). Though modern classroom science can be regarded as a sub-culture of the Western scientific culture, it needs to be considered also in itself as cultural entity. We get this from Grandy and Duschl's (2008) assertion of western science as the practice of scientists which focuses on knowledge production while classroom science focuses on science learning. (5) Learners engage in cultural border crossings from home culture, into classroom science culture through that of western science in their learning of science (Aikenhead 1996). In addition, learners experience to varying degrees of difficulties when moving from their home worlds into that of the world of school science, and (6) learners are in need of help for them to resolve any cultural conflicts so that they navigate and negotiate their border crossings.

To further unpack this cultural approach to science education, we find it necessary to understand Western science as one of the compartments of western knowledge (Barnhardt and Kawagley 2005) which was initially extricated from the Western culture (Otulaja et al. 2011). In fact, the social institution of the concept of science in the Western world is traceable to 1831 (Aikenhead and Ogawa 2007) thereby earmarking the start of its development as an enterprise with its own unique cultural identity (Millar 2004).

Viewing modern classroom science as situated within the Western scientific culture, at the same time acknowledging its uniqueness of culture, places it internally and externally to western and indigenous cultures respectively. We logically suggest that cultural border crossing comes in different forms. These are on one hand within (intra or domestic) Western culture borders for learners with a western cultural background. Their crossing of borders from that of their home culture into science culture and modern classroom science is all internal to their western culture. Indigenous learners, on the other hand, can be said to engage in external border crossing as they move from their external IK/S based culture into western scientific culture, and modern classroom science. For the Canadian Indigenous learners, Snively and Corsiglia (2001) describe this experience as trans-cultural learning which in some sense we view as applicable to African indigenous learners. In comparison, the ease in crossing intra and inter borders can come to be regarded as different, with the former being more complex than the later.

Based on the argument we presented in the preceding paragraph, we find it sensible to predict that if all learners learn IK/S integrated classroom science, they all, whether with western or indigenous background, will be involved in both intra and inter border crossing. The learners with a western cultural background would cross internal borders in learning classroom science from a Western scientific worldview and external when they learn it from an IK/S worldview. The converse can be true with reference to indigenous learners. In this regard, we situate our CACS as addressing issues of cultural relevance to all learners irrespective of their cultural backgrounds. In this way, CACS aligns with the goal suggested by Brayboy and Castagno (2008) of promoting and encouraging both Indigenous and Western scientific knowledge in the classroom. By including IK/S in school science, learners of all cultural backgrounds are developed to understand nature from both ways of knowing. This goal falls within the complementary approach to integrating IK/S and modern classroom science suggested by Alaskans Barnhardt and Kawagley (2005).

Ogunniyi (2011) notes that despite all perceived benefits and the intense advocacies for IK/S-science curricula reforms, these have rarely been translated into tangible science classroom practices in many parts of Africa. This can be looked at as a strong indicator of underlying threats to the integration of IK/S and modern classroom science. In fact, it has been observed by the likes of South African scholars as Hewson, Javu and Holtman (Hewson and Ogunniyi 2011) that the task of integrating IK/S and modern classroom science has proved to be intricate and, for this reason, problematic, particularly for teachers in many nations around the world.

Literature points to global multiple teacher struggles for integrating indigenous knowledge and modern classroom science. Most teachers struggle to understand the nature of science and that of their own IKS (see Ogunniyi 2007). In addition, these teachers struggle to teach science effectively because of their inadequate and inept teaching strategies (Hewson et al. 2009).

Multifaceted shifts inherent in any curriculum reform may be a major source of the teacher-related hurdles to the successful implementation of indigenous knowledge and science curricula reforms highlighted above. These shifts include teacher-dispositions, school-community relations, curriculum materials, content and pedagogy (Castagano and Brayboy 2008). These problems are ripple affected by the fact that curricula change in itself, in fact, is difficult (Kathleen Davis 2003). In Zimbabwe, this problem is exacerbated by policy directives to integrate IK/S and MCS that are not accompanied by guiding frameworks on how to bring about this integration. The challenge of including IK/S in the teaching of MCS is not peculiar to Zimbabwe only but, as revealed by Ogunniyi (2011), has largely remained a perennial problem in many African countries. All the problems of integrating IK/S with modern classroom science are largely grounded in indigenous knowledge and western science different worldviews (Snively and Corgslia 2001). So, the observations that science teachers are reluctant to bring IK/S into their classrooms in South Africa (Ogunniyi 2007) and Zimbabwe (Ngara 2007) are not surprising.

Defining the problem

The impact of a theoretical framework in any research process is pervasive and far reaching. In espousing the importance of the theoretical framework Merriam and Sampson (2000) assert that it does not only affect the conceptualisation of the problem and development of methodological design, but also lays the foundation of the study; provides a reference point for the interpretation of the research findings; and also demonstrates how the study advances knowledge. The problem, however, becomes that a theoretical framework suitable for any particular study such as the integration of IK/S into modern classroom science is not readily available in literature, but rather needs to be constituted. As we have already alluded to in previous sections, the task of integrating IK/S and modern classroom science is a complex one. In turn, it invokes complexities and challenges involved in the process of studying this phenomenon. Good research (process) that produces a good outcome is founded on an appropriately informing theoretical framework. To this point a crucial question related to the complex and intricate relationship between IK/S and western science as well as the task of integrating IK/S with modern classroom science, which has largely remained unresolved in science education, is: what can be done to advance the teaching of IK/S in science classrooms? The challenge here is on building an appropriate theoretical framework that anchors and guides an in-depth inquiry into indigenous knowledge and modern classroom science integration. Specifically, the problem this paper is addressing is of how to theorise the integration of indigenous knowledge into school science considering their distinct worldviews.

The purpose of this conceptual paper

This paper seeks to constitute and examine a theoretical framework for integrating indigenous knowledge and modern classroom science. We do this to yield new theoretical insights into how the very important but complex task of integrating indigenous knowledge with modern classroom science might be done. Its objective then is to explicate a multifocal approach to the integration of these two knowledge forms using the example of traditional plant healing (TPH) as a case in point. In addition, we envision that as we engage in the process of constituting CACS, the complexities, tensions and dilemmas that characterize the design and implementation of indigenous knowledge and modern classroom science integrated curricula; and, at the end, point out how indigenous knowledge might be appropriately integrated with modern classroom science. The purpose of this theoretical paper is pursued within the framework of our understanding of the concept of theoretical framework.

In the process of theorising the construction of CACS, we use the concept of theoretical framework within this meaning espoused by Labarree (2011). Labarree refers to a theoretical framework as concepts and existing theories that inform and guide a particular study. We think of a theoretical framework from the analogy of the spectacles. Spectacles are frames holding lenses for vision correction. The lenses can be uni-focal, bi-focal or multi-focal, to define their visual purpose. Single-focal lenses are for either distance viewing or reading purposes. The multi-focal lenses have integrated different foci within the same frame which brings about multi-vision. Each focus enables the eyes to work under different circumstances. Analogous to the multifocal lens is our CACS theoretical framework that houses a number of theories and concepts that can accommodate the different approaches of integration indigenous knowledge and modern classroom science and their worldviews. A multi-focal lens approach to integrating indigenous knowledge and modern classroom science opens the space for examining and addressing the complex nature of this task for which, in our view, a single theory or concept is inadequate. Our construction of CACS theoretical framework forms the subject of the next section.

Culturally-aligning a classroom science theoretical framework

The CACS theoretical framework we constitute in this section is an integration of the concepts of knowledge, classroom science, traditional plant healing, indigenous knowledge, worldviews and integration. CACS, a multi-focal lens for integrating IK/S with modern classroom science, emerges through our examination of these concepts using one or more theories within five broad domains. These domains are: the tetrahedral model of knowledge; situating classroom science and TPH within their worldviews; cultural border crossing; the concepts of integration; and indigenous classroom science as an outcome of integration. Since indigenous knowledge is unique, with local knowledge held by people of a particular land of origin or living (Shizha 2007), we find it necessary to develop CACS within the African context. However, readers may find CACS transferable to other similar contexts in non-Western countries (e.g. Taiwan, Saudi Arabia, and South Africa); or Western countries (e.g. Australia, New Zealand, America). We round off our constitution of CACS with its structural representation that shows the interrelatedness of these five domains. This is followed by a brief discussion of its implications on the research process that focuses on the integration of indigenous knowledge with modern classroom science.

The tetrahedral model of knowledge

The purpose of building a tetrahedral framework of knowledge is for characterization and understanding of what knowledge entails in the context of this paper. The intention here is to provide a theoretical underpinning of knowledge that can be of help in the identification, understanding and documentation of TPH. This is basically because most African indigenous knowledge has limited documented repositories (Otulaja et al. 2011). In Africa, most libraries and information centres, according to Jabulani Sithole (2007), an indigenous knowledge culture and globalization researcher, are faced with a plethora of challenges in the documentation and communication of indigenous knowledge. Given this challenge, the suggestion by Agrawal (1993) becomes desirable that particularization of IKS, that is its identification and separation of useful indigenous knowledge, should precede its inclusion into school science. By identification and separation of indigenous knowledge, we presume documenting and understanding it. Further, we interpret useful IKS here as selecting indigenous knowledge from its cultural matrix, referred to as IKS by Vhurumuku et al. (2009), rather than suggesting that some indigenous knowledge is useless. As we have already alluded to (see page 2), IKS is the foundation from which indigenous knowledge that can form school science can be selected and documented, as modern classroom science was documented from western science. With reference to the South African context, these authors suggest that documentation and vetting of indigenous knowledge should precede textbook writing for school use. It is from these documents that not only the school textbooks on IK are written but they also form frames of references for developing curricula.

Our development of CACS is premised on the basic assumption that there is need for understanding what knowledge is in order to search for indigenous knowledge and document it. The documented knowledge forms the repository from which indigenous knowledge can be drawn for classroom science. Our development of this knowledge model is guided by and framed within two fundamental theories of knowledge, pluralism and multiculturalism. The knowledge pluralism lens is social construction perspective knowledge that posits it as existing in plural form (Shizha 2007). On the other hand, multiculturalism, in general, upholds the principles of cultural diversity as normal and accords equal status to different cultures. In essence, the plurality of knowledge comes from cultural diversity. Knowledge, therefore, needs to be looked at as a universal cultural heritage and resource (Odora Hoppers 2002, p.8). In fact, the argument by Snively (2009) that science entails knowledge produced through observation and experience, from its Latin word origin *scientia,* supports the assertion that science is habitant in every culture, western or indigenous (Snively and Corsiglia 2001).

We regard both the plurality and multiculturalism approaches to knowledge as significant to CACS in that they uphold both indigenous knowledge and western science as legitimate forms of knowledge rooted in different cultures. As much as western science is grounded in western culture (Aikenhead 1996), so are indigenous knowledge and the science in there are grounded in indigenous cultures (Otulaja et al. 2011). The implication here, in accordance with Louter (1993), is that the natural world can be studied from multiple ontological and epistemological perspectives. This creates space to understand nature from indigenous knowledge and western science perspectives and upholds multicultural science assumptions. Within this frame of reference, Lederman's (1992) view of western science as a way of knowing and interpreting experiences with nature and values/beliefs attached to the development of that knowledge can as well be applied to indigenous knowledge. In support of our transferred Lederman's point of view of science to a broader level that also embraces indigenous knowledge is the definition of indigenous knowledge put forward by Warren (1991), as a body of knowledge built up by a group of people through generations of living in close contact with nature. Therefore, as Aikenhead (1996) contend, science is a rational, empirically based description and explanation of nature from any cultural perspective, Western or non-Western.

The multicultural science frame of reference that embraces plurality and multiple cultures of knowledge leads us to proposing the four (product, process, enterprise and paradigm) domain model knowledge. We tag it the E3P tetrahedral knowledge model. We develop E3P tetrahedral knowledge model from the logic that science is knowledge grounded in different cultures. It exists in either IK or western science form. Given this form of reasoning, we zoom up the four dimensions of western science gleaned in literature to apply also to indigenous knowledge and knowledge in general. The four descriptions of the term science are adopted with reference to western science as process of inquiry or product (Vhurumuku and Mokeleche 2009); science as an enterprise (Millar 2004) and an epistemology (Ogunniyi 2007). To capture both the ontological and epistemological cultural ways of knowing, we use the term paradigm which depicts the same meaning as a worldview.

Figure 1 shows the four interactive domains of process (P), Product (P), Enterprise (E) and worldview/paradigm (P). Each is positioned on each vertex of the tetrahedral metaphor to show their complex interactions. Each domain predetermines the unique identity of the cultural enterprise, Western scientific or Indigenes. The human element (enterprise) is central to this model in that it is a people's cultural way of knowing (paradigm) that guides them in their inquiry (processes) of nature to understand the world and generate knowledge (products). This knowledge guides us to not only recognizing indigenous knowledge "as a knowledge system that describes and explains nature in

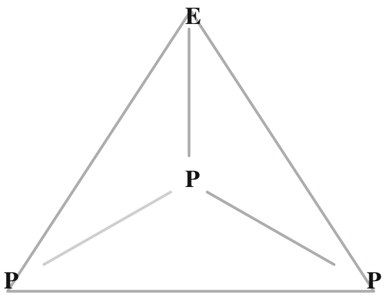


Fig. 1 The E3P tetrahedral model of knowledge

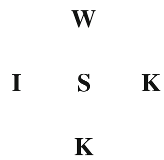


Fig. 2 Convergence and divergence areas of WSK and ISK

culturally powerful ways" as an initial step towards culturally relevant science reforms, as suggested by Aikenhead (2006), but also to understand it.

The sciences in indigenous knowledge and western science forms can be differentiated from their forms of existence. We adopt the term Western 'science' knowledge (WSK) with reference to western science to depict it as an extricated body of scientific knowledge from western culture. On the other hand, we adopt the term indigenous science knowledge (ISK) to reflect that this form of science in indigenous knowledge is interwoven with its other various forms. Figure 2 illustrates our thought that indigenous knowledge and western science, though rooted in different worldviews, have areas of knowledge convergence and divergence.

The convergent relationships of indigenous knowledge and western science can be visualised through the common term science. The question we raise in relation to the convergence and divergence of IK and western science is: what science knowledge domains can converge and which are divergent? Our E3P tetrahedral model guides us in searching for the answers, which can be found in the E3P areas of product, process, paradigm and enterprises. For example, the research conducted by Ogunniyi (2011) shows that the fermentation of cassava as a scientific product of both indigenous scientific knowledge and western scientific knowledge is an area of convergent. The divergent areas are those engaged in different processes as guided by their epistemologies. Within each of these divergent areas some commonalities between indigenous scientific knowledge and western scientific knowledge may also be searched and established. It therefore makes sense to think of the product as common.

While it is easier to find the E3P domains of knowledge in western scientific knowledge, the same cannot be said of indigenous scientific knowledge. This is because these two knowledge forms have been in a state of contestation (Shizha 2006) for many centuries but not at par. With western scientific knowledge dominating and subjugating the indigenous scientific knowledge, it is well documented and is easily accessible in school text books whilst the later has been a neglected area. This has ripple affected the many people, especially teachers, as they tend to regard indigenous knowledge as deficient and therefore not suitable classroom science (Constance Ngara 2007). For this reason, establishing the nature of indigenous knowledge for its inclusion in classroom science in Africa becomes a pre-requisite to the integration process. This is supported by Aikenhead's (2006) proposition of recognizing indigenous knowledge "as a knowledge system that describes and explains nature in culturally powerful ways" as an initial step towards culturally relevant science reforms. The E3P tetrahedral model of knowledge helps us to understand indigenous knowledge for the purposes of selecting that indigenous knowledge which forms classroom science.

We also take note of the three categories of educational research suggested by Barnhardt and Kawagley (2005, p. 8–23) in our development of CACS: namely, the nature of indigenous knowledge and its inclusion in school science; the epistemologies underlying indigenous knowledge systems; and pedagogical approaches appropriate for integrating indigenous knowledge with western science in science classrooms. Our E3P model of knowledge addresses the first category. The second category provides the need to establish the worldview underlying the TPH form of indigenous knowledge. In addition, we also situate the modern classroom science currently on offer in most African schools within its western scientific worldview. We do this in order to create opportunities for identifying areas of convergence and divergence between indigenous scientific knowledge and western scientific knowledge.

Situating classroom science and traditional plant healing within their worldviews

According to Moyra Keane, in South Africa, attempts to include indigenous knowledge in textbooks usually consist of traditional ''bits that fit'' into the current syllabus (2008, p.589). This can also be said about teachers' attempts to teach indigenous knowledge in their classrooms. A syllabus is a curriculum document that provides a framework for teachers on the purpose, content and pedagogy of any science subject. In most African secondary schools, the common science subjects are inclusive of general or natural science, biology, chemistry, physics, and physical science. It is important to note that this fragmented approach to integrating indigenous knowledge in these science subjects, as observed by Moyra, is also common in many African nations such as Zimbabwe. In caution, Moyra contends that such an approach to the integration of indigenous knowledge with modern classroom science merely provides surface understanding of indigenous knowledge rather than an in-depth understanding of it. Given the privileged status of western science over indigenous knowledge (Snively and Corsiglia 2001), we regard this approach as perpetuating it, and therefore making it problematic for indigenous knowledge integration into modern classroom science.

To integrate indigenous knowledge into modern classroom science in a legitimate manner calls for a thorough exploration of the indigenous learners' underlying, pervasive, and often implicit worldviews (Odora Hoppers 2002). In literature, some authors dichotomise IK and western science as distinct forms of knowledge that are often incompatible with each other. Other authorities like Barnhardt and Kawagley (2005) recognise the commonalities and differences between these two knowledge forms. We take up the later view and initially examine indigenous knowledge and western science in their stand alone capacities to obtain an in-depth understanding of the nature of each. We situate both modern classroom science and TPH within their western science and indigenous knowledge worldviews respectively. This creates a platform for us to compare these two knowledge forms, establish how they speak to each other and their convergent areas as well as divergent ones. All this enables stakeholders interested in indigenous knowledge and modern classroom science integration to identify opportunities for integration.

Classroom science and the western scientific worldview

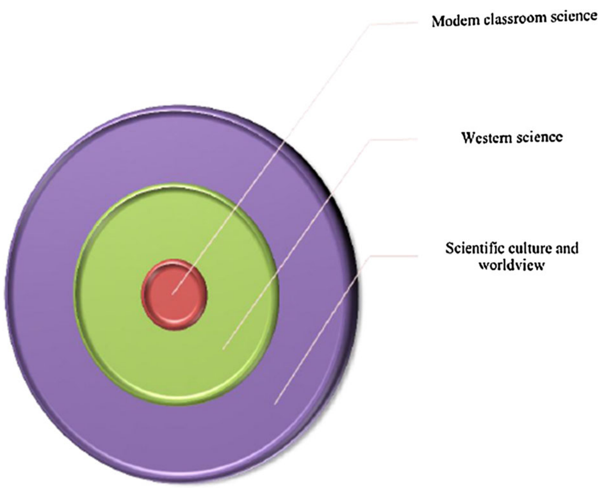
To date classroom science offered in African secondary schools is largely Western oriented (Makhurane 2000) as we have alluded to in earlier sections. In other words, the content, pedagogy and purpose of these modern classroom science subjects are framed within the western scientific worldviews of the natural phenomenon (Lee et al. 2011). Content as applied here does not simply refer to subject matter of products and processes of science but is also inclusive of the nature of science and the scientific enterprise. We regard this inclusive approach to content as fundamental to understanding the nature of modern classroom science content from all the four E3P domains of western scientific knowledge. In support of our E3P inclusive approach to content is Meyer and Crawford (2011) who advocate for the teaching of the nature of science. Nature of science describes the epistemology of science or values and beliefs inherent in the development of scientific knowledge (Lederman 1992).

We embrace Meyer and Crawford's view (2011) of science as a cultural way of knowing and recognise a curriculum as a selection from culture (Lawton 1978). Western science, though a select from western culture, is rooted in its own unique scientific worldview that uniquely identifies it (Godin and Gingras 2000). It is cast as rational, value-free, objective and therefore universal (Harding 1998).

Different syllabi of modern classroom science subjects are a select from the western science, its scientific culture and worldview. In Fig. 3 we represent the relationship of modern classroom science to western science and its worldview.

Modern classroom science passes on western science to learners in the context of schooling. It is situated within the western scientific worldview as shown in Fig. 3. Despite this relationship, as Grandy and Duschl (2008) contend, western science differs from modern classroom science. The former, as the practice of scientists, focuses on knowledge production (worldview) whilst the later focuses on science learning (pedagogy). Pedagogy means how to teach WSK content in a way that facilitates learners' understanding and appreciation of it. It means "the thinking and theorising about how learners learn (Kidd and Czerniawski 2010, p. 6). Pedagogy shapes the real classroom practices in terms of teaching strategies, tools and techniques. According to Aikenhead (2006) and Cobern (2000), conventional science, that is,

Fig. 3 Modern classroom science, western science and worldview relationship



modern classroom science, teaching overemphasizes a scientific worldview of understanding nature and neglects the worldviews of indigenous learners.

Traditional plant healing and the African indigenous worldviews

The worldview description provided by Cobern we have presented in previous pages of this paper interrelate IK/S and culture. The African indigenous worldview embraces *Unhu/ Ubuntu* and spirituality that provide a foundation of their IKS and indigenous knowledge as illustrated in Fig. 4 below.

The *Unhu/Ubuntu* worldview describes interdependent ways of living among members of African communities (Keane 2008). It cherishes a way of being and belonging to an existing community web of complex relationships. At individual level, it inculcates the values of honest, care, good manners and regard for others, self-discipline, courage, diligence and tolerance (Nziramasanga 2012). These values serve to instil intrinsic individual responsibility of togetherness with other members of the community.

According to Dei (2010, indigenous worldviews uphold connections and interrelatedness of the natural (human, land, water and animals) and the metaphysical (intuition and spirituality) worlds. To illustrate, the Zimbabwe Shona expression *"mwana wevhu"* translates to "son of the soil". But it is a metaphor that signifies that indigenous Zimbabweans belong to their land, depend on it for a living and are connected to it through their ancestral line of deity. The conservation of this land for it to continue to support life is through spiritual guidance (consultations, dreams, intuition). Within the African worldview of spirituality, upon death, the spirit of the dead person is recognised as central to the lives of the living. It continues to guide and educate its progeny; and is therefore honoured and recognised as a community member through *Unhu/Ubuntu.*

Indigenous knowledge exists in various forms. One such category of indigenous knowledge upon which to select the indigenous knowledge that can form part of classroom science is traditional medicine (see Fig. 3). It resides in local "human archives" (Otulaja et al. 2011) often referred to as traditional healers; *sangoma* in South Africa and *n'anga* in Zimbabwe. Though there are varied definitions of traditional medicine in literature, in this paper we refer to it as an indigenous health management system that constitutes use of

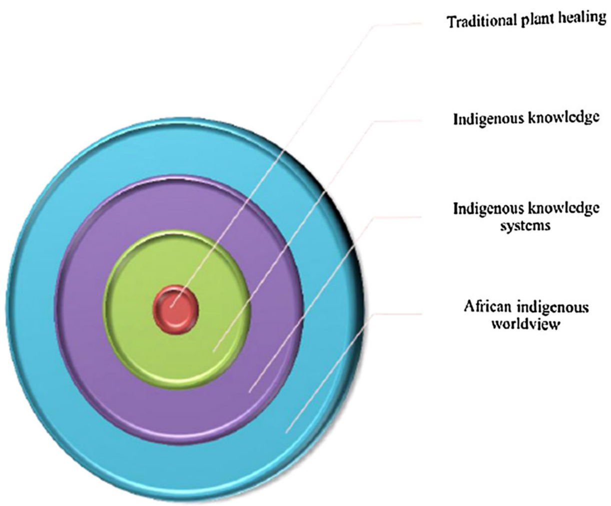


Fig. 4 TPH, indigenous knowledge, IKS and African indigenous worldview relationship

plant and animal materials supported by spiritualism (Hewson et al. 2009). Our focus is on TPH, that is, the use of medicinal indigenous plants for healing.

The spiritual world of the Africans and their *Unhu/Ubuntu* in honour of both spirits and their mediums seem to determine their trust in traditional healers' management of their health. The traditional healers are often consulted by not only Africans in rural areas, but also, as Otulaja et al. (2011) note, by urbanized, "westernized" indigenes as well as pharmaceutical companies seeking local knowledge. However, researchers such as Moyra Keane (2008) have come to realise that such knowledge is secretive and confidential and not easily divulged serve for prevention and treatment of illness.

Given this understanding of TPH, IKS, indigenous knowledge and African indigenous worldview espoused above, for the TPH form of indigenous knowledge to be appropriately included into classroom science there is need to unveil its knowledge as specific to a given locality. Since this knowledge has limited documentation (Sithole 2007), its understanding needs to be obtained from their traditional custodians. This search for understanding TPH should be sought through the E3P tetrahedral model of knowledge to document it. The documented TPH knowledge forms a repository from which content and pedagogy for classroom science is drawn.

Cultural border crossing

In 1996 Aikenhead proposed a learning of science theory, cultural border crossing, informed by the basic assumption of science as a culture in its own right. This theory explains learning of science as being bounded by indigenous (home) and classroom science (school) cultures. Drawing on this theory, we have, in earlier sections of this paper, defined the cultural borders involved as either internal or external. Learners involved in crossing internal borders as they learn modern classroom science are those whose cultural backgrounds are western. On the other hand, indigenous learners cross external borders as they engage with modern classroom science.

Aikenhead (2001) draws on Hawkins and Pea (1987) and Costa's work (1995) to explain the range of differences between a learners' home culture and that of modern classroom science. He articulates that the learners' transition of cultural borders that ranges from ease to very difficult or virtually impossible relate to how synchronised these cultural worlds are. He explains that where these cultures are synchronised or harmonized, learners' transition into the cultures of school science through that of western scientific culture becomes fairly easy. In our view this happens when learners are crossing internal borders. In the event that those learners engage in crossing external borders, Aikenhead contends, this results in disharmony between the learner's home culture and that of school science. As such, the learner would experience difficulties in crossing such borders. Aikenhead proposes four types of transitions between the different cultures of learners as they learn science, namely, smooth, managed, hazardous, and impossible. These forms of transitions come with congruent, different, diverse and highly discordant worlds respectively.

In viewing modern classroom science on offer in most schools in Africa, it entails that to African indigenous learners, border crossing from their home culture into that of classroom science is external. The negotiation of such borders, therefore, can never be easy and smooth but rather difficult. For learners with a western culture background learning science in school, their crossing of these cultural borders may be relatively less difficult to that of the indigenous counter-parts. If indigenous knowledge is included in modern classroom science we regard an outcome of this process as indigenised classroom science.

We refer indigenised classroom science to mean integrated classroom science unit or units or the entire curricula with any form of indigenous knowledge, such as TPH. Cultural border crossing based science then would entail learners of different cultural backgrounds crossing both external and internal borders. This will be dependent on the approach, IK or western science descriptions and explanations of the natural phenomenon. This will not only assist learners in making connections between science and their indigenous knowledge (Aikenhead 2001) but also help these learners connect classroom science with the cultural backgrounds in a dual manner (Glasson, Mhngo, Phiri and Lanier 2010).

We view this frame of crossing cultural borders in the learning of science as appropriate to the advancement of multicultural science education, which we refer to here as CACS, goals proposed by Aikenhead (1997) in Braboy and Castagno (2008 p.740). These suggest that the overall goal of culturally relevant science education needs to be that of developing in learners an understanding of the world from different cultural worlds.

The alternative pathway integration model

There are various conceptions and theories of integration provided in literature. We use these to develop our alternative pathway integration model. This is guided by the basic assumption that we draw from Ogunniyi's (2011) the assertion of views on including indigenous knowledge into classroom science. He posits that these views range from total exclusion to inclusion through cautious and partial inclusion. Ogunniyi uses the term exclusion to mean rejection of an alternate way of knowing in favour of those of western science. This view perpetuates indigenous knowledge repression by the scientific world. The converse is true for inclusion. At school level, this exclusive-inclusive assumption will keep indigenous knowledge out of classroom science. We use the term inclusion to mean the same as integration.

From the inclusion–exclusion assumptions, we propose four basic pathways to integrating indigenous knowledge into modern classroom science, namely, parallel, divergent, convergent and substitutive. In the sections which follow, we present a discussion of each category of integration using appropriate theories for each that we draw from literature. Importantly, these integration pathways should not be viewed as disparate but rather as occupying a continuum from total exclusion through partial inclusion to total inclusion.

Divergent integration

Battiste (2002) and Simpson (2004) are some of the leading indigenous scholars who argue that integration of indigenous knowledge into established modern classroom science perpetuates subjugation of and waters down indigenous knowledge. The fragmented approaches of integrating indigenous knowledge into school text books oversimplify indigenous knowledge preservation, Keane (2008) argues. She further posits the need to get an in-depth understanding of indigenous knowledge as a prerequisite to integrating it in a legitimate way. These ideas, from our view, point towards a form of integration that serves to maintain indigenous knowledge and western science in disparate positions until such a time indigenous knowledge is well developed. The expression "well developed" does not mean to denounce indigenous knowledge but rather to underline the need to bring it out of its secretive box, document it and select from it indigenous knowledge for classroom science purposes. To these authors, integration can only come into consideration when both the content and pedagogy for indigenous knowledge has been fully developed and well documented. We call this pathway to integration divergent.

Parallel integration

The contiguity argumentation theory (CAT) proposed by Ogunniyi (2004) explains how people contrast ideas based on a worldview that differs from their own and engage in internal conversations in order to make a decision. The decision making in the learning of science entails choosing between the two alternatives ways of explaining a natural phenomenon, indigenous knowledge or western science. To illustrate this competition between these knowledge forms, we use the example of the cause of HIV/AIDS. A cultural point of view perceives HIV/AIDS as rooted in superhuman forces while Western medicine says it is caused by a virus. People juxtapose such ideas in search of some meaningful co-existence. One outcome of this search process is when learners fail to find meaningful co-existence between these ideas. When this happens, the ideas remain disparate and incompatible (Jegede and Aikenhead 1999).

In fact, according to Ogunniyi, there are five possible outcomes of the internal conversation presented above, namely, dominance, suppression, assimilation, emergence and equipollence. These relate to one idea overriding the other idea; the suppression of one dominating idea in favour of an emerging one; the infusion of a new idea into prior ideas; the generation of new ideas on new grounds with linking them to prior ideas respectively. Any of these cognitive outcomes can occur in an individual engaged in internal or external conversation to attain conceptual equilibrium (Hewson and Ogunniyi 2011).

Contiguity argumentation theory speaks to the co-existence of indigenous knowledge ideas and western science in the learners. We suggest bringing another form of integration; parallel, based on the assumptions of CAT. Parallel integration occurs when indigenous knowledge and western science ideas are both recognised as legitimate and allowed to co-exist in learners. Importantly, we place these cognitive outcomes on an escalated continuum, from dominance to equipollent learning. We propose that parallel integration comes from scaffolding learners to progress through cognitive outcomes of dominance, suppression, assimilation and emergence. At the equipollent phase, learners would be able to understand classroom science from both indigenous knowledge and western science worldviews.

The current indigenous knowledge and western science relation status at classroom level is that the later dominates the former. There is no parallel integration. Parallel integration should occur by creating a classroom environment which not only facilitates cultural border crossing learning, but also scaffolding learners from dominance to equipollent phase. Scaffolding learning entails the process of mediating learning, where one person (e.g. teacher) provides the other (learner) with support to help escalate other achievable stages (Lev Vygotsky 1978); and this is not happening in most African science classrooms today. As pointed out by Battiste (2002), the goals of culturally relevant science need to guide teachers and learners in animating indigenous knowledge in science classrooms. We interpret this to facilitating co-existence of indigenous knowledge and western science at classroom level, which we present as parallel integration of indigenous knowledge into modern classroom science.

Convergent integration

Some indigenous scholars are advocating for the synergistic approach to the integration of indigenous knowledge and western science at classroom level. Barnhardt and Kawagley (2005) refer to this approach as synthesising these two knowledge forms into one comprehensive and holistic system. Shizha (2006) describes this approach as knowledge hybridization. We use this synergistic approach to suggest yet another integration approach, the convergent approach. We ground this integration pathway in the third space theory advanced by Bhabha (1994). Bhabha, in this theory, draws similarities from both the first space (home culture) and the second space (classroom science) to form an intersection called the third space (synthesised science). Within this approach, indigenous classroom science is regarded as the outcome of this synthesis approach to integration. Whatever remains in the first and second spaces are aspects of knowledge which cannot be synthesized but can coexist in satisfying parallel integration.

Substitutive integration

Snively and Corsiglia (2001) posit a common observation among indigenous scholars that in educational settings where modern classroom science is taught, it is taught at the expense of indigenous scientific knowledge, "which may precipitate charges of epistemological and cultural imperialism" (p.7). That modern classroom science is offered in African schools has come to be acknowledged as a colonial aftermath and legacy. Dei (2010) and many other scholars are of the notion that the privilege and dominance of western science need to be deconstructed. In some indigenous communities, some educators in collaboration with community members are advocating for and engaged in the process of decolonising indigenous knowledge (Smith 1999). We regard the extreme end of the decolonisation process in indigenous communities as displacement of modern classroom science by an indigenous knowledge curriculum. We call this form of integration substitutive. We view this substitutive integration is a possibility emerging from the activist approaches of the likes of Odora Hoppers who are angry with the consequences of colonialism.

Indigenous classroom science as an outcome of integration

Our logical assumption here is that the different indigenous knowledge and modern classroom science integration pathways lead to different nature of indigenised classroom science. For example, one of the goals of multicultural science education suggested by Aikenhead (1997) can be argued to be aligned to parallel integration more than convergence. In this case, Aikenhead (1997) argues that one of the goals of multicultural science education is to "emphasize on learning about what constitutes reality for various cultural groups", as alluded to in the above section. Content and pedagogy of such indigenised classroom science, therefore, should similarly be aligned to the purpose.

CACS theoretical model

In Fig. 5 we provide a visual representation of the CACS theoretical model we have discussed above within an African-Zimbabwean context. The blue boundary reflects the Zimbabwean context of integrating TPH and modern classroom science. This model shows five inter-related features of: (1) domains of knowledge, (2) plurality of knowledge, (3) cultural border crossing, (4) alternative pathways to integration, and (5) indigenized classroom science. As discussed in the previous section on integration pathways, each of the features (1), (2), (4) and (5) is looked through a lens (theory or theories) appropriate to it, therefore, we regard CACS as multifocal.

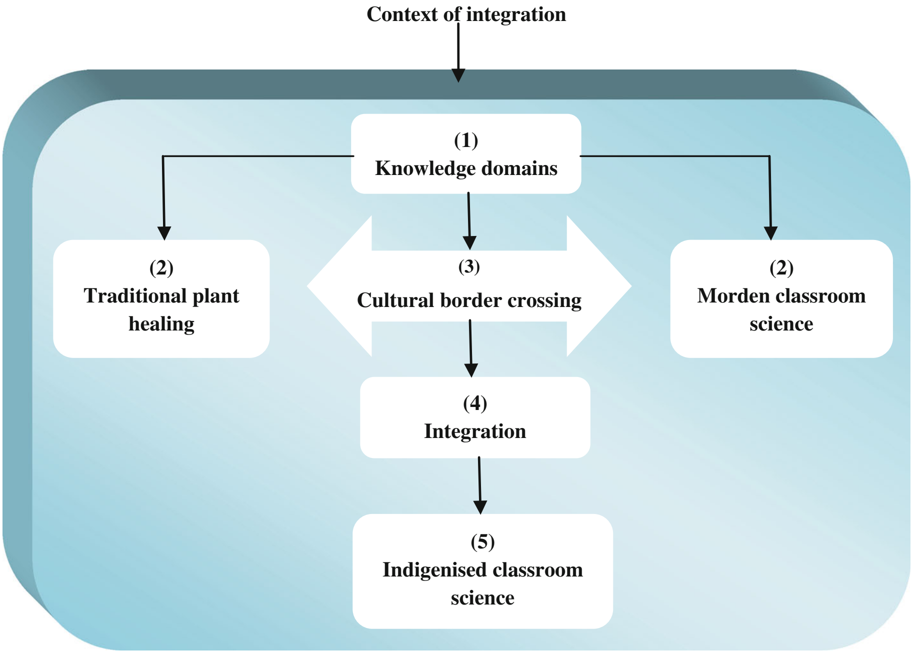


Fig. 5 CACS theoretical madel

Domains of knowledge

Aspect (1) depicts a four dimensional perspectives of each of the two forms of knowledge (indigenous knowledge and western science) under investigation. These are knowledge: as held by a particular cultural group (enterprise); as a way of knowing (paradigm); as an inquiry (process); and as an outcome of inquiry (product). Aikenhead (2006) suggests recognizing indigenous knowledge "as a knowledge system that describes and explains nature in culturally powerful ways" as an initial step towards culturally relevant science reforms. In this regard, not only the understanding of TPH but modern classroom science as well from cultural and worldview perspectives need to be done before considering their integration. According to this CACS model, this becomes an initial step towards the integration of TPH into modern classroom science.

Plurality of knowledge

The identification of the knowledge forms to be integrated as informed by the model that knowledge exists in plural form follows the framing of knowledge within the E3P. Aspect 2 of the CACS exemplifies that. Within this plurality of knowledge model, TPH represent a form of indigenous knowledge, and modern classroom science rooted in western scientific worldview. This plurality of knowledge lens makes it possible examine and understand each of these two knowledge forms in their individual capacities through the E3P lens.

Cultural border crossing

The double arrow labelled cultural border crossing in Fig. 5, the CACS model above, (aspect 3) illustrates border crossing as theoretically underpinning integration of indigenous knowledge and modern classroom science. We have illuminated on how this model supports integration on previous pages of this paper. Within this CACS model, this entails that the four different pathways to integration under discussion in the ensuing section are all underpinned by border crossing.

Alternative pathways of integration

Integration of TPH and modern classroom science is subsequent event to understanding them in their distinct forms and the establishment of the possibility of their integration. This aspect (4) of the CACS model depicts a multi-perspective framework of integration. We basically argue for four pathways to integration of indigenous knowledge into modern classroom science as discussed in the earlier section. We subsume that each pathway is supported by an appropriate theory. The equipollent outcome of CAT is a theoretical framework we use to underpin parallel integration. The convergent integration is supported by the theory of hybridisation or the third space model. The divergent integration is supported by theory that indigenous knowledge and western science as both legitimate knowledge forms but in disparate positions. Substitutive integration emerges from theory of relevance that disregards the learning of modern classroom science by indigenous learners as irrelevant.

The understanding of integration from a multi-pathway perspective guides us in understanding the integration standpoint of different stakeholders in science education in their context. Context here entails the influence of politico-socio-economical, historical and technological developments as well as globalisation factors on the issue of integrating indigenous knowledge into modern classroom science.

Outcome or product of integration

Aspect 5 shows that whatever integration strategy/route is taken it culminates into a particular nature of indigenous classroom science.

Implications and conclusion

In the paper, we have theorised a CACS model for the integration of indigenous knowledge into modern classroom science that takes into consideration their distinct worldviews. In our theorisation of this model, we have used the integration of TPH into modern classroom science as a case in point. Our elaborate theoretical framework shows how complicated the task of integrating indigenous knowledge with modern classroom science is. The complex nature of this task has necessitated the employment of more than one theory in order to come up with a more comprehensive description of the phenomena under study. CACS as a multi-perspective model of integrating indigenous knowledge into modern classroom science consist of five interrelated domains. It starts from framing knowledge within the E3P model. The identification of the indigenous knowledge form, for example TPH, to be integrated into modern classroom science follows. This is followed by establishing the appropriate integration pathway from four alternatives and the emic standpoint of the participants in such a study. The cultural view of science that frames it in a multi-cultural science perspective, paves the way to understanding of learning of science as a border crossing process. According to our CACS model, border crossing anchors and precedes integration of indigenous knowledge and modern classroom science. Our CACS model culminates into particular nature of indigenous classroom science despite integration pathway is taken.

The complex nature of integrating indigenous knowledge into modern classroom science and CACS as its proposed framework also call for a research methodology that is appropriate and inclusive. This is in order to cater for the varied knowledge systems under investigation. Since we are dealing with two opposite worldviews, it would be appropriate to accord appropriate research strategies for each of the worldviews, and that is the challenge that we will face up to in the article on methodology.

References

Agrawal, A. (1993). Indigenous and scientific knowledge: Some critical comments. *Indigenous Knowledge and Development Monitor 3*.

Aikenhead, G. S. (1996). Science education: Border–crossing into the sub–culture of science. *Studies in Science Education, 27*, 1–31.

Aikenhead, G. S. (1997). Towards a first nations cross-cultural science and technology curriculum. *Science Education, 81*, 217–238.

Aikenhead, G. S. (2000). Renegotiating the culture of school science. Retrieved June 27 2012 from http://www.usask.ca/education/people/aikenhead/renegotiating.htm.

Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education, 85*, 180–188.

Aikenhead, G. S. (2006).Towards decolonizing the Pan-Canadian science framework. *Canadian Journal of Science, Mathematics and Technology Education, 6*(4), 387–399.

Aikenhead, G. S., & Ogawa, M. (2007). Indigenous knowledge and science revisited. *Cultural Studies of Science Education, 2*, 539–620.

Barnhardt, R., & Kawagley, A. O. (2005). Indigenous knowledge systems and Alaska Native ways of knowing. *Anthropology and Education Quarterly, 36*, 8–23.

Battiste, M. (2002). *Indigenous medicine and pedagogy in First Nations Education: A literature review with recommendations*. Indian and Northern Affairs: Ottawa.

Bhabha, H. (1994). *The location of culture*. London: Routledge.

Brayboy, B. M. J., & Castagano, A. E. (2008). How Native sciences inform "informal science learning"? *Cultural Studies of Science Education, 3*, 731–750.

Castagano, A. E., & Brayboy, M. J. B. (2008). Culturally responsive schooling for indigenous youth: A review of literature. *Review of Educational Research, 78*(4), 941–993.

Cobern, W. W. (2000). *Everyday thoughts about nature*. Boston: Kluwer.

Cobern, W., & Loving, C. (2001). Defining "science" in a multicultural world: Implications for science education. *Science Education, 85*(1), 50–57.

Costa, V. B. (1995). When Science is "another world": Relationships between worlds of family, friends, school and science. *Science Education, 79*(3), 313–333.

Davis, K. S. (2003). "Change is hard'': What science teachers are telling us about reform and teacher learning of innovative practices. *Science Education, 87*, 3–30.

Glasson, E. G., Mhango, N., Phiri, A., & Lanier, M. (2010). Sustainability science education in Africa: Negotiating indigenous ways of living with nature in the third space. *International Journal of Science Education, 32*(1), 125–141.

Godin, B., & Gingras, Y. (2000). What is scientific and technological culture and how is it measured? A multidimensional model. *Public Understanding of Science, 9*, 43–58.

Grandy, R. E., & Duschl, R. A. (2008). Consensus: Expanding the scientific method and school science. In R. E. Grandy & R. A. Duschl (Eds.), *Teaching scientific inquiry: Recommendations for research and implementation* (pp. 304–325). Rotherdam: Sense.

Guilmet, G. M. (1984). *American Indian and Alaska Native Education for high Technology: A Research Strategy for Creating Culturally Based Physical Science and Mathematics Education.* Paper presented at the Annual Meeting of the Society for Applied Anthropology, Toronto, Ontario, Canada. March 15, 1984.

Guo, C.-J. (2007). Issues in science learning: An international perspective. In S. K. Abell & N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 227–256). Mahwah: Lawrence Erlbaum Associates.

Harding, S. (1998). *Is science multicultural?: Postcolonialisms, feminisms, and epistemologies*. Bloomington, IN: Indiana University Press.

Hawkins, J., & Pea, R. D. (1987). Tools for Bridging the Cultures of Everyday and Scientific Thinking. *Journal of Research in Science Teaching, 24*(4), 291–307.

Hewson, M. G., Javu, T. J., & Holtman, B. H. (2009). The indigenous knowledge of African traditional health practitioners and the South African Science curriculum. *African Journal of research in Mathematics, Science and Technology Education, 13*(1), 5–18.

Hewson, M. G., & Ogunniyi, M. B. (2011). Argumentation- teaching as a method to introduce indigenous knowledge systems into science classrooms: opportunities and challenges. *Cultural studies of Science Education*, *6*, 679–692. http://www.ecologyandsociety.org/vol12/iss2/art34/.

Jegede, O. (1996). In support of culturally and individually responsive science. *Science Education, 80*, 101–104.

Jegede, O. J., & Aikenhead, G. S. (1999). Transcending cultural borders: Implications for science teaching. *Research in Science and Technology Education, 17*(1), 45–66.

Kawagley, A. O. (1995). A Yupiaq world view—a pathway to ecology and spirit. In *Prospect Heights*. IL: Waveland Press.

Keane, M. (2008). Science education and worldview. *Cultural Studies of Science Education, 3*, 587–621.

Kidd, W., & Czerniawski, G. (2010). Successful teaching 14–19: Theory, practice and reflection. London: Sage.

Klos, M. L. (2006). Using cultural identity to improve learning. *The Educational Forum, 70*, 363–370.

Labaree, R. (2011). *The purpose of this guide is to provide advice on how to develop and organize a research paper in the social science* http://libguides.usc.edu/writingguide.

Lawton, D. (1978). *Theory and practice of curriculum studies*. London: Routledge and Kegan Paul.

Lederman, N. G. (1992). Students and teachers conceptions of the nature of science: A review of literature. *Journal of Research in Science Teaching, 29*, 331–359.

Lee, H., Yen, C.-F., & Aikenhead, G. S. (2011). Indigenous Elementary Students "Science Instruction in Taiwan: Indigenous Knowledge and Western Science". Research in Science Education, On line first.

Loubser, J. A. (2005). Unpacking the expression "indigenous Knowledge systems". *Indilinga-African Journal of Indigenous Knowledge Systems, 4*(1), 74–88.

Louter, B. (1993). *We have never been modern*. Cambridge: Harvard University Press.

Lyons, T. (2006). The puzzle of falling enrolments in physics and chemistry courses: Putting some pieces together. *Research in Science Education, 36*, 285–311.

Mack, E., Augare, H., Cloud-Jones, L. D., Davı′d, D., & Gaddie, H. Q. (2012). Effective practices for creating transformative informal science education programs grounded in Native ways of knowing [online first]. *Cultural Studies of Science Education*.

Makhurane, P. (2000). Science and technology in Zimbabwe in the Millennium. *Zimbabwe Journal of Educational Research, 12*(3), 62–79.

Merriam, S. B., & Simpson, E. L. (2000). *A guide to research for educators and trainers of adults* (2nd ed.). Malabar, FL: Krieger.

Meyer, X., & Crawford, B. (2011). Teaching science a cultural way of knowing: Merging authentic inquiry, nature of science, and multicultural studies. *Cultural Studies of Science Education, 2*, 525–547.

Millar, R. (2004). *The role of practical work in the teaching and learning of science*. Paper prepared for the Meeting: High School Science Laboratories: Role and Vision, 3-4 June 2004. National Academy of Sciences, Washington, DC.

Nakashima, D. J. (2000). *What relationship between scientific and traditional systems of knowledge?* In E. Shizha (2007). Analysis of problems encountered in incorporating indigenous knowledge in science teaching by primary school teachers in Zimbabwe. *Alberta Journal of Education Research, 53*(3), 302–319.

Ngara, C. (2007). African ways of knowing and pedagogy revisited. *Journal of Contemporary issues In Education,2*(2), 7–20.

Nyawaranda, V. (1998). Doing a qualitative research Study. *Bullet of Teacher Education, 2*(1), 1–13.

Nziramasanga, C. T. (2012). *The 1999 Presidential Commission of Inquiry into Education and Training (CIET) report: Implementation enigmas or revelations*. Paper presented at the Symposium on the Presidential CIET University of Zimbabwe.

Odora-Hoppers, C., A. (2002). Indigenous knowledge and the integration of knowledge systems: Towards a conceptual and methodological framework. In C. A. Odora Hoppers (Ed.), *Indigenous knowledge and the integration of knowledge systems: Towards a philosophy of articulation* (p. 2–22), South Africa, New Africa Books.

Ogawa, M. (1995). Science education in a multiscience perspective. *Science Education, 79*(5), 583–593.

Ogunniyi, M. B. (1988). Adapting western science to traditional African culture. *International journal of science education, 10*(1), 1–9.

Ogunniyi, M. B. (2004). The challenge of preparing and equipping science teachers in higher education to integrate scientific and indigenous knowledge systems for their learners. *South African Journal of Higher Education, 18*(3), 289–304.

Ogunniyi, M. B. (2007). Teachers' stances and practical arguments regarding a science Indigenous knowledge curriculum: Part 1. *International Journal of Science Education, 29*(10), 1189–1207.

Ogunniyi, M. B. (2011). The context of training teachers to implement a socially relevant science education in Africa. *African Journal of Research in MST Education, 15*(3), 98–121.

Otulaja, F., Cameron, A., & Masinga, A. (2011). Rethinking argumentation-teaching strategies and indigenous knowledge in South African science classrooms. *Cultural Studies of Science Education, 6*, 693–703.

Sefa Dei, G. J. (2010). *Teaching Africa: Towards a Transgressive Pedagogy*. London: Springer.

Seth, S. (2009). Putting knowledge in its place: science, colonialism, and the postcolonial. *Postcolonial Studies, 12*(4), 373–388.

Shizha, E. (2006). Legitimizing indigenous knowledge in Zimbabwe: A theoretical analysis of postcolonial school knowledge and its colonial legacy. *Journal of Contemporary Issues in Education, 1*(1), 20–35.

Shizha, E. (2007). Analysis of problems encountered in incorporating indigenous knowledge in science teaching by primary school teachers in Zimbabwe. *Alberta Journal of Education Research, 53*(3), 302–319.

Shizha, E. (2010). The interface of neoliberal globilization, science education and indigenous knowledge in Africa. *Journal of Alternative Perspectives in Social Sciences, 2*(1), 27–58.

Simpson, L. (2004). Anticolonial strategies for recovery and maintenance of Indigenous knowledge. *American Indian Quarterly, 28*, 373–384.

Sithole, J. (2007). The challenges faced by African libraries and information centers in documenting and preserving indigenous knowledge. *IFLA Journal, 33*(2), 117–123.

Smith, T. L. (1999). *Decolonising methodologies: Research and indigenous people*. London and New York: Zed books and University of Ontago Press.

Snively, R. (2009). Money from the sea: A cross-cultural indigenous science problem solving activity. *Green Teacher, 86*, 33–38.

Snively, R., & Corsiglia, J. (2001). Discovering indigenous science: Implications for science education. *Science Education, 85*, 6–34.

Vhurumuku, E., Holtman, L., Milkalsen, O., & Kolsto, S. D. (2008). The rationale for science education, curriculum change and reform in sub-Saharan Africa: The case of Zimbabwe. In L. Holtman, C. Julie, O. Mikalsen, D. Mutetwa & M. Ogunniyi (Eds.), *Sub-Saharian Africa: African minds* (pp 225–247). South Africa.

Vhurumuku, E., & Mokeleche, M. (2009). The nature of science and indigenous knowledge systems in South Africa, 2000–2007: A critical review of the research in science education. *African Journal of Research in Mathematics Science and Technology Education, 1*, 96–114.

Vygosky, L. S. (1978). *Mind in society: the development of higher psychological processes.*

Warren, D. M., & Rajasekaran, B. (1993). Indigenous knowledge: Putting local knowledge to good use. In M. Cole, V. John-steiner, S. Scriber & , E. Souberman (Eds and trans.). *International Agricultural development, 13*(4), (pp. 8–10). Cambridge: Harvard University Press.

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