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INTEGRATING WESTERN AND INDIGENOUS KNOWLEDGE SYSTEMS: THE BASIS FOR EFFECTIVE SCIENCE EDUCATION IN SOUTH AFRICA?

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Abstract – This article responds to a call for rethinking the science that we teach to school learners in South Africa. Much of the debate on the nature of science and science learning is reflected in a body of literature which analyses the tensions between disparate perspectives on science education. Post-colonialists, feminists, multiculturalists, sociologists of scientific knowledge and those who refer to themselves as indigenous researchers argue that science is not universal but locally and culturally produced. Universalists on the other hand, argue that modern Western science is superior to indigenous perspectives on the natural world because of the former's advanced predictive and explanatory powers. The fact that indigenous knowledge has been included in South Africa's recently developed National Curriculum Statements invites a fresh look at the kind of science that is taught to South African school learners. In this article the author argues for a (dis)position that moves the debate beyond the binary of Western science/indigenous knowledge. Ways in which Western science and indigenous knowledge might be integrated are explored.

Résumé – INTÉGRER LES SYSTÈMES OCCIDENTAUX ET INDIGÈNES DU SAVOIR : LE FONDEMENT D'UN ENSEIGNEMENT EFFICACE DES SCIENCES EN AFRIQUE DU SUD ? - Cet article répond à un appel pour repenser l'enseignement des sciences que nous délivrons aux écoliers en Afrique du Sud. Une grande partie de la discussion sur la nature des sciences et de l'étude des sciences se voit reflétée dans un corpus littéraire analysant les tensions subsistant entre des visions divergentes de l'enseignement des sciences. Post-colonialistes, féministes, multiculturalistes, sociologues du savoir scientifique et ceux qui se définissent comme des chercheurs indigènes soutiennent que les sciences ne sont pas universelles mais localement et culturellement produites. Les Universalistes d'autre part soutiennent que les sciences occidentales modernes sont supérieures aux visions indigènes du monde de la nature, ces dernières mettant en avant des pouvoirs de prédiction et d'explication. Le fait que le savoir indigène ait été inclus dans les Rapports sur les Programmes d'Études Nationaux récemment développés en Afrique du Sud invite à poser un regard neuf sur le genre de sciences enseignées aux écoliers sud-africains. Dans cet article, l'auteur plaide pour une (dis)position déplaçant la discussion au delà de l'alternative science occidentale/savoir indigène. On examine des possibilités d'intégration de la science occidentale et du savoir indigène.

Zusammenfassung – DIE VEREINBARKEIT WESTLICHER UND INDIGENER WISSENSSYSTEME: BASIS FÜR EINE ERFOLGREICHE WISSENSCHAFTLICHE BILDUNG IN SÜDAFRIKA? – Dieser Artikel ist eine Antwort auf den Aufruf zum Nachdenken über die Art der Wissenschaft, die wir Schülern in Südafrika beibringen. Debatten über die Natur der Wissenschaft und des wissenschaftlichen Lernens finden größtenteils im Spiegel einer Literatur statt, die die Spannungen zwischen unterschiedlichen Perspektiven wissenschaftlicher Bildung analysiert. Im Postkolonialismus, Feminismus, Multikulturalismus, in der Wissenssoziologie und in der indigenen Forschung wird die Auffassung vertreten, dass

Wissenschaft nicht universal ist, sondern lokal hergestellt wird. Auf der anderen Seite steht die universalistische Position, derzufolge die moderne westliche Wissenschaft aufgrund ihrer fortgeschrittenen prädiktiven und explanatorischen Kraft indigenen Sichtweisen der natürlichen Welt überlegen sei. Die Tatsache, dass indigenes Wissen in die kürzlich entwickelten National Curriculum Statements einbezogen wurde, lädt dazu ein, die Wissenschaftsvermittlung in südafrikanischen Schulen mit neuen Augen zu betrachten. Der Artikel tritt für eine Weiterbewegung der Debatte über die Zweiteilung westliche Wissenschaft/indigenes Wissen hinaus ein und erforscht neue Wege der Vereinbarkeit von westlicher Wissenschaft und indigenem Wissen.

Resumen – LA INTEGRACIÓN DEL SISTEMA DE CONOCIMIENTO OCCIDENTAL CON EL DE LA POBLACIÓN AUTÓCTONA: ¿UNA NUEVA BASE PARA LA EDUCACIÓN EN CIENCIAS EN SUDÁFRICA? - Este artículo es la respuesta a una llamada a reconsiderar las ciencias que enseñamos a los alumnos en Sudáfrica. Una gran parte de los debates sobre la naturaleza de las ciencias y el aprendizaje de las ciencias se ve reflejada en un cuerpo literario que analiza las tensiones existentes entre diferentes enfoques de lo que debe ser la educación en ciencias. Postcolonialistas, feministas, multiculturalistas y sociólogos del conocimiento científico y aquellos que se autodenominan 'investigadores indígenas' sostienen que la ciencia no es universal, sino que se produce a nivel local y cultural. Los universalistas, por otra parte, sostienen que la ciencia occidental moderna es superior a la visión del mundo natural de la población autóctona, a raíz del poder de explicación y predictivo de la primera. El hecho de que los conocimientos de la población originaria hayan sido incluidos en los Programas Nacionales de Estudio de Sudáfrica, desarrollados recientemente, ofrece la posibilidad de formarse una idea muy actual sobre la clase de ciencias que se están enseñando a los alumnos sudafricanos. En este artículo, el autor aboga por una actitud que promueva el debate sobre la división en ciencias occidentales y conocimientos indígenas, y explora los modos de integrar las ciencias occidentales con los conocimientos de la población autóctona.

Резюме – РЕФОРМЫ УЧЕБНЫХ ПРОГРАММ В НАЧАЛЬНЫХ ШКОЛАХ В АФРИКЕ: МИФ И ДЕЙСТВИТЕЛЬНОСТЬ – В данной статье проводится критический анализ введения и реализации новых школьных учебных программ в Африке, основанный на примере подхода на основе умений и навыков (SBA). Во многих странах подход SBA был выбран в качестве наиболее подходящего и соответствующего метода для изменения своей школьной учебной программы и улучшения качества образования. В данной статье анализируется, как осуществляются эти новые учебные программы на основе подхода SBA в начальных школах в Мавритании. Результаты показывают, что основные проблемы достижения успехов школьниками заключаются больше в эффективной реализации учебных программ в классе, чем в их содержании. Дополнительный анализ показывает, что такой результат подтверждается также и в других африканских странах. В качестве фонового анализа представляется история подхода SBA, определяются его цели, а также дается оценка его ограничениям с педагогической точки зрения. Слабые места данного подхода акцентируются для того, чтобы принимать во внимание потребности и реальность африканских образовательных систем. Такие разнообразные элементы приводят к выводу о том, что, если реформы учебных программ часто являются необходимыми в африканских странах, то они не могут быть средством для решения проблемы качества образования.

Methodological (dis)position

This article is the product of "a number of initially separate threads of meaning – requests, recollections, reflections and ruminations" (Gough 2004: 17). It represents the serendipitous coming together of initially disparate threads to shape an object (or objects) of inquiry. As part of an ongoing intellectual project concerned with attempts to decentre Western science, the author recently completed an article capturing some of the key debates on multiculturalism/universalism and science education. At about the same time he was also preparing a keynote address for a postgraduate conference on educational research. The address, which focused on educational research in developing countries included some critical reflections on the growing (sub)-field of school effectiveness research. These two activities coincided with a general invitation/call to present a paper at an education conference which had as its theme *Prerequisites for Effective Education*. The separate requests served as the starting point for exploring potential connections between School Effectiveness Research (SER) and debates on the nature and learning of science.

The author finds inspiration for this way of researching/writing from the works of Deleuze and Guattari (1987) and Richardson (2001). Deleuze and Guattari (1987) contrast "arborescent" and "rhizomatic" thinking. Arborescent means having treelike characteristics. Therefore arborescent thinking refers to thinking that branches from a single idea, thought, plan, problem or question – this way of thinking is reflected in much of Western thought. Unlike a tree with a single tap-root, rhizomes spread in all directions, creating a network in which every point connects to every other one. Rhizomatic thinking therefore is thinking that arises from different points and spreads in all directions to form networks of thoughts. Furthermore, Richardson (2001) argues that writing does not merely represent or bear testimony to inquiry, but is itself a form of inquiry. She notes:

> I write because I want to find something out. I write in order to learn something that I did not know before I wrote it. I was taught, though, as perhaps you were, too, not to write until I knew what I wanted to say, until my points were organized and outlined. No surprise, this static writing model coheres with mechanistic scientism, quantitative research, and entombed scholarship (Richardson 2001: 35).

So, in this article networks of thought are developed through writing, beginning with a discussion on school effectiveness research.

School effectiveness: an entry point

A detailed discussion on School Effectiveness Research is not provided here but simply an outline of some key aspects of the discourse with a view to exploring a nexus between school effectiveness and how students learn science. The focus of the discussion will be on South African learners, but may also have applicability to other societies both inside and outside of Africa.

Carney (2003: 87) points out that School Effectiveness Research is associated with a particular version of globalization in ascendancy, that is, with the rise of neo-liberal and neo-conservative policies. It favours certain approaches to school organization, management, curriculum, teaching and assessment that place an emphasis on efficiency and accountability to state-sanctioned knowledge and values. A key notion in this approach to educational research is that of the "school effect" – that which makes some schools perform better than others even though they are located in similar environments. This dominant view of School Effectiveness Research, which largely ignores the socio-cultural contexts in which schools are located, offers no obvious points of contact between school effectiveness and how African students learn science.

However, several general criticisms have been made of School Effectiveness Research, and in some instances SER has been disparagingly referred to as "policy entrepreneurship", "ethnocentric pseudo-science" and "politically promiscuous" (see Carney 2003: 89). In developing countries school effectiveness research continues to be narrowly focused on cognitive achievement as the primary measure. Carney (2003: 90) argues that such a focus captures only a fragment of what counts in schooling and perhaps of what counts in education more broadly. In such a narrowly focused approach it is not only the qualitative dimensions of schooling that are neglected, but contextual/environmental effects are also statistically controlled and eventually ignored. Put another way, emphasis is placed increasingly on elaborate statistical procedure rather than epistemological justification. But separating contextual factors from school factors is problematic, because as Hatcher (1998: 280) writes: "[school cultures are a] product of the interaction between the official culture of the school and the cultures of pupils". Or as Wrigley (2004: 232) elaborates:

> The complex process by which economic and cultural features of the extra-school environment are carried into the school through the individual and collective consciousness of pupils, reworked by teachers' assumptions and reactions, and transformed into school cultures cannot be modelled by statistical methods which attempt to parcel out responsibility between societal, school and individual factors.

Harber and Davies (1997) argue that we require broader approaches to effectiveness that are based on an in-depth understanding of the context-specific socio-political causes of school ineffectiveness. It may reasonably be assumed that Harber and Davies' (1997) view includes the centrality of socio-cultural factors in determining school (in)effectiveness and by implication student learning. It is the influence of socio-cultural factors on student learning that is the key concern of this article and which serves as the point of connection between school effectiveness and the way(s) in which African students learn science.

Non-Western learners' learning of science

In every society different worldviews interact. For example, what a child learns about the world through religion may be different from what is taught/learned in school science. For non-Western learners, interaction between two worldviews characterizes much of their school experience, complicating the learning process and potentially resulting in cognitive conflict or as the literature describes it, cognitive dissonance/perturbation. In Africa, schools are the sites where most learners first experience the interaction between African and Western worldviews. It is therefore crucial that teachers working in these contexts (especially Western teachers) be aware of this interaction and understand the way it could complicate the learning process. Jegede (1999: 119) suggests that the culture of a learner's immediate environment plays a significant role in learning and that it determines how concepts are learned and stored in the long-term memory as schemata.

Much has been written over the years about complications African learners experience when learning science (see Ogawa 1986; Ogunniyi 1987, 1988; Jegede 1989; Jegede and Okebukola 1989; Jegede and Fraser 1990; Okebukola and Jegede 1990; Jegede 1996). Despite this body of literature that has been produced and the fact that indigenous knowledge systems reside among the majority of South Africans, the topic has not been given the attention it deserves. Focusing on and extending some of the key debates on African students' learning of science is crucial at this point in time, given that the promotion of indigenous knowledge systems has been identified as one of the principles on which the National Curriculum Statements for both General Education and Training (GET) and Further Education and Training (FET) in South Africa are based. The National Curriculum Statement for General Education and Training was phased in during the year 2001 and the National Curriculum Statement for Further Education and Training was phased in during the year 2006. The obvious implication of this principle is that indigenous knowledge should be included in the discursive terrains of all learning areas/subjects.

The inclusion of indigenous knowledge in South African curriculum policy statements is a positive step and could provide opportunities for debate on interaction(s) between Western and indigenous worldviews. Effective learning, however, will depend on teachers' understanding of this interaction and their ability to manage classroom discourses related to this matter. Also, a growing interest in school effectiveness research (the dominant discourse) internationally as well as in South Africa, with its emphasis on relationships between school factors and cognitive achievement, may result in neglecting to examine the socio-cultural determinants of learning. These two reasons provide a strong justification for the central focus of this article, that is, the integration of indigenous and Western worldviews as the basis for effective science learning in South Africa. The dominant view of school effectiveness ignores the influence of socio-cultural factors on student learning and therefore is an inadequate model for understanding how African students learn science.

As mentioned before, much has been written about the problematic aspects of African students' learning of science. A summary of key findings of reported research on how indigenous learners learn science shows that:

- Socio-cultural background has a greater effect on learning than subject content;
- the indigenous worldview inhibits the initial adoption of Western science by learners;
- indigenous (non-Western) learners are involuntarily selective when making observations in science classrooms;
- the indigenous learner might explain natural phenomena in ways that appear as non-rational in the perception of Western science, but the learner experiences no contradictions in his/her conceptual system;
- knowledge learned about school science and through traditional ways is compartmentalized by the learner giving rise to what Wiredu (1980: 23) has termed "a kind of ethnic schizophrenia".

(Adapted from Jegede 1999: 128)

Jegede (1999: 128–129) identifies two important implications of these findings. Firstly, any science curriculum that does not take particular account of the indigenous worldview of the learner risks destroying the framework through which the learner is likely to interpret concepts. Secondly, an indigenous learner can perform excellently in a Western science classroom without assimilating the associated values. As Jegede (1999: 129) writes: "[A] 'good' scientist at school can at home be a 'traditionalist' without any feeling of cognitive perturbation or dissonance." The latter point will become clearer when Jegede's theory of collateral learning is discussed next.

Jegede's theory of collateral learning

Jegede (1995, 1999) posits that a duality of thought is created in the memory and schemata of indigenous learners when they learn Western science, because of the resilience of the indigenous knowledge framework. It is also a way they use to cope in a learning environment that is hostile to what indigenous learners bring to the science classroom. He argues that this situation results in collateral learning. Jegede (1999: 133) identifies four types of collateral learning: parallel, simultaneous, dependent and secured. Importantly, these types of collateral learning should not be viewed as disparate but rather as occupying a continuum, and that "a student could be helped to progress through them for meaningful learning to occur" (Jegede 1999).

Parallel collateral learning

Parallel collateral learning occurs when learners acquire and maintain opposing schemata about a concept and idea in their long-term memory when learning new science concepts. The learner does not experience conceptual conflict, but readjusts the memory to accommodate changing contexts of learning. Jegede (1999: 134) writes that parallel learning is particularly evident when indigenous learners first come into contact with school science and that these learners allow the new information to coexist in their schemata while they are still attempting to make sense of them.

Simultaneous collateral learning

Jegede (1999: 134) points out that for a concept to be embedded in the long-term memory of a learner, the information needs to be processed over a period of time. Therefore, at the point when learners are exposed to a new concept in the science classroom, they might still be processing information in relation to this concept that they learned at home or in their cultural/environmental setting. A situation arises when learners simultaneously learn about a concept from two different worldviews. Simultaneous collateral learning thus places learners in a position to assess similarities to and differences between ideas from different worldviews in relation to the concept being learned.

Dependent collateral learning

Dependent collateral learning occurs when schemata from one worldview are presented which challenge those of another worldview enabling the learner to modify existing schemata. No radical restructuring of the existing knowledge base occurs, but learning of a new idea is triggered by what is already known. Jegede (1999: 134) writes: "This means that a currently held belief (indigenous or otherwise) is held tentatively to be altered by the construction of new knowledge from the new schema or the rejection of a current one."

Secured collateral learning

Acquiring knowledge or an intellectual skill is a gradual and incremental process rather than a single event. To ensure that this prolonged process of learning is effective, the learner has to resolve what he/she might experience as cognitive conflict or mental dissonance in the knowledge base embedded in his/her long-term memory. In other words, the indigenous learner has to resolve the mental conflict created by the Western science learned and the indigenous knowledge base brought to the classroom. The process of resolving the cognitive dissonance culminates in the learner evaluating seemingly disparate explanatory frameworks and drawing from them what Jegede (1999: 135) calls "a convergence towards commonality." He writes: "This strengthens the learning process and secures the 'new conception' in the long-term memory" (Jegede 1999: 135).

This discussion demonstrates the point made earlier that, rather than being seen as disparate, the four types of collateral learning should be viewed as a continuum against which science learning can be understood in a socio-cultural framework. It is the author's view that Jegede's (1995, 1999) thesis of collateral learning contributes greatly to theoretical debates on science learning in non-Western and multicultural contexts. Moreover, his work has practical significance for policy-makers and science teachers who perform their work in such contexts. However, much of his discussion frames the African indigenous worldview and Western worldview as being disparate. While these worldviews are disparate if science or knowledge is understood as *representation* only, they are not disparate if science is also viewed as *performance*. Science is both *representation* and *performance*, and if *science as performance* is emphasized, greater credence might be given to Jegede's notion of secured collateral learning – which, it will be argued, is the basis for effective science learning in an African context.

Science as *performance*

In my view, Western science and indigenous knowledges may be viewed either as disparate epistemologies or as complementary frameworks depending on whether one views *science/knowledge as representation* or *science/knowledge as performance*. In his seminal work *The Structure of Scientific Revolutions*, Kuhn (1970) identifies two distinct notions of the term paradigm, namely, paradigm as *disciplinary matrix* and paradigm as *exemplar*. The former denotes the "entire constellation of beliefs, values, techniques, and so on shared by the members of a given community" (Kuhn 1970: 175). The latter refers to some sort of element in that constellation, "the concrete puzzle-solutions which, employed as models or examples, can replace explicit rules as the basis for the solution of the remaining puzzles of normal science" (Kuhn 1970: 175). Turnbull (2000: 8) points out that Kuhn's (1970) first use of the term paradigm is somewhat analogous to a global theory such as Newtonian physics and is subject to revolutionary change. The second use (exemplar), on the other hand, is closer to the standard meaning of the term – "a sample problem solution which can be extrapolated to other problems" (Turnbull 2000: 8). Exemplars are based on agreements about which kinds of problems are sufficiently similar so that they can be treated in the same way. The implication of this is that disparate problems can be perceived as being similar and known techniques and solutions can be applied to them. Turnbull (2000: 8) notes that exemplars are the product of tacit knowledge that is learned by doing science rather than by acquiring rules for doing science.

Table 1 below illustrates a representationalist perspective of knowledge, where African indigenous knowledge is viewed as distinct from Western science. To borrow Kuhn's words, "the entire constellation of beliefs values, techniques, and so on" shared by members of traditional African and Western communities is perceived as distinctly different. Separating knowledge systems/worldviews conceptually helps us to think and learn (i.e. for heuristic purposes). However, there is a danger of our constructions/representations being perceived as mirroring reality to the extent that we try to make reality fit representations of it. For example, the author remembers that as a university science student, when asked to sketch objects that he had observed with

Table 1. Assumptions underlying Western(?) science and indigenous knowledge systems

Assumptions underlying indigenous knowledge systems	Assumptions underlying Western science
Nature is real, and partly observable and testable.	Nature is real, observable and testable
Space is real, has definite dimensions but is ultimately incommensurable.	Space is real and has definite dimensions.
Time is real, continuous and cyclical.	Time is real and has continuous, irreversible series of duration
Matter is real and exists within time, space and the ethereal realm.	Matter is real and exists within time and space.
Events have both natural and unnatural causes.	All events have natural causes.
The universe is orderly, metaphysical, partly predictable and partly unpredictable.	The universe is orderly and predictable – that is, nature is not capricious.
Generalizations have causal, personal, rational/non-rational, logical/non-logical dimensions.	Scientific laws/generalizations are causal, logical, rational, impersonal and universal.
Language is important as a creative force in the workings of both the natural and the unnatural worlds.	Language is not important to the workings of natural world.
Knowledge is a critical part of culture.	Science is culture free.
Facts are both tested and experiential	Scientific facts are tested observations.
Knowledge is based on a monistic worldview.	Science is based on a dualistic world-view.
Generalizations are relative statements which do not purport to have universal application.	Scientific generalizations (laws and theories) are declarative statements with universal application.
Humans are capable of understanding only part of nature.	Humans are capable of understanding nature.

Adapted from Ogunniyi (2004: 292–293).

the aid of a light microscope, he (and his fellow students) often turned to the textbook diagram of the object to measure the accuracy of his work. As a student of science his confidence was not in the work he had performed (what he drew from what he had observed), but in how accurately it resembled the representation(s) of the object(s) as it/they appeared in a textbook. School and university students learn early on to view *science as representation* to the neglect of *science as performance*. What students do not learn is the situated messiness of science and, for that matter, the situated messiness of all knowledge production processes. Furthermore, in representations of Western and African indigenous knowledges, Western science often is portrayed as superior, universal, and as not having the "cultural fingerprints" that appear to be much more conspicuous in other knowledge systems (Gough 1998: 508). Also, representations of Western science are used as criteria for declaring "other" knowledges as non-science. A representationalist perspective on knowledge therefore produces an incommensurability perspective, that is, that Western science and indigenous knowledges are incompatible or that indigenous ways of knowing may be recognised as a particular way of understanding the world, but that they are not science.

However, understanding knowledge production as performance enables seemingly disparate knowledges to work together so as to produce new knowledge spaces, what Turnbull (1997: 560) terms "third spaces" or "interstitial spaces". It is widely recognised by sociologists of scientific knowledge and philosophers of science that, even though knowledge systems may differ in their epistemologies, methodologies, logics, cognitive structures or in their socio-economic contexts, a characteristic that they all share is their localness (see Rouse 1987; Latour 1988;Shapin 1994; Turnbull 1997, 2000). Moreover, knowledge is not simply local but located/situated, that is, it has place and creates space. When knowledge is produced it is assembled from heterogeneous components and given coherence through the deployment of social strategies and technical devices. As Star (1989: 388) writes:

> [Knowledge production] is deeply heterogeneous: different viewpoints are constantly being adduced and reconciled … Each actor, site, or node of a scientific community has a viewpoint, a partial truth consisting of local beliefs, local practices, local constants, and resources, none of which are fully verifiable across all sites. The aggregation of all viewpoints is the source of the robustness of science.

As mentioned, the common element of all knowledge systems is their localness. However, their differences lie in the way they are assembled "through social strategies and technical devices for establishing equivalences and connections between otherwise heterogeneous and incompatible components" (Turnbull 2000: 13). As Turnbull (1997: 553) writes:

> Some traditions move it and assemble it through art, ceremony and ritual; [Western] science does it through forming disciplinary societies, building instruments,

> standardization techniques and writing articles. In both cases, it is a process of knowledge assembly through making connections and negotiating equivalences between the heterogeneous components while simultaneously establishing a social order of trust and authority resulting in a knowledge space.

Viewing knowledge in this way enables seemingly disparate knowledge traditions to be integrated so as to disrupt the dichotomy between Western science and African indigenous knowledge. In short, science as representation refers to: abstractions such as theories and laws; the idea of a scientific method; descriptions of the world in textbooks; and so on. Science as performance, however, refers to the doing of science, that is, science is a human and social activity that is messy, heterogeneous and situated.

Pedagogical implications

There is justified concern about the state of science education in South Africa. The percentage of learners who pass Grade 12 with Science and Mathematics on the Higher Grade is small and declining. South Africa has performed badly on international surveys such as those conducted as part of the Trends in International Mathematics and Science Study (TIMSS). Responses to a perceived crisis in South African science education have in the main focused on interventions at school level, often parochially aimed at improving achievement at the Grade 12 level. Such approaches are framed within school effectiveness discourses, which tend to ignore the influence of socio-cultural factors on learning. This is despite the fact that science education research conducted in southern Africa over the past three decades has shown that culture has a great impact on learning and school achievement – that the geo-socio-cultural environment represents the link between what is already known and what is learned. Moreover, it has shown that effective science education in South Africa depends on understanding how non-Western children learn. Jegede's thesis of collateral learning provides useful insights into how indigenous students learn Western science. His thesis has important implications for teachers' work and teacher education programmes. Firstly, teachers need to understand the importance of not denigrating or discrediting the indigenous knowledge that learners bring to the classroom because it serves as the framework against which they learn science and also provides the trigger for learning science. Secondly, the four types of collateral learning provide teachers with a framework to mediate and scaffold indigenous learners through different phases of science learning. Importantly, the National Curriculum Statement for General Education and Training and the National Curriculum Statement for Further Education and Training provide legal enablements for facilitating processes towards secured collateral learning, since indigenous knowledge systems form part of the discursive terrains of all learning areas/subjects.

But how might learners be scaffolded through the different phases of science learning? Jegede and Aikenhead (1999: 55) suggest that the teacher needs to take on the role of cultural broker, that is, he/she should help learners mediate or negotiate cultural borders. They suggest that in some instances the teacher needs to be a *tour guide* cultural broker and in other instances a *travel agent* cultural broker. When cultural border crossing (from life-world culture to school science culture) is difficult for the learner, the teacher needs to take on the role of a *tour guide*, whereby the teacher takes learners to the principal sites in the culture of science and coaches them on what to look for and how to use it in their everyday lives. In doing so the teacher uses an extended repertoire of methods. In other instances where learners require less guidance when border crossing, the teacher may take on the role of *travel agent*, whereby the teacher provides learners with incentives such as topics, issues, activities or events that create the need to know the culture of science. In other words, border crossing occurs through academic bridges and less through guidance. Scaffolding learners through parallel and simultaneous collateral learning would require the teacher to play the role of *tour guide*, whereas scaffolding learners through/from dependent learning to secured collateral learning might require the teacher to chiefly take on the role of *travel agent*. Needless to say, both approaches assume that learning/teaching occurs within an ecocultural paradigm, that is, that science content used in classrooms strongly relates to and uses the life-world of the learner as the focus and starting point of learning. Furthermore, both approaches are dependent on interactive teaching strategies. By way of illustration, two interactive strategies will now be discussed.

In South African classrooms learners experience cognitive dissonance when learning about certain phenomena in science classrooms. For example, the scientific perspective that lightning is caused by the discharge of electricity between clouds or from a cloud to the earth is in conflict with learners' cultural understanding that lightning is caused by, for example, witchcraft. Two strategies may be useful in helping learners to deal with cognitive perturbation in this instance. The first strategy is what Bajracharya and Brouwer (1997: 436) termed "a narrative approach". This approach involves arranging learners in small group discussions on questions such as, "Is lightning caused by witchcraft?" What this approach does is to provide to a small degree, a conceptual ecocultural paradigm that can serve as the basis for the teacher to take on the role of cultural broker. The second approach is one that was introduced by Aikenhead (1996), where border crossing is made concrete by asking learners to divide the page in their notebook in half to form two columns: "my ideas" and the "culture of science ideas". To return to the lightning example, learners would record their own ideas and beliefs about lightning in the one column, and in the other column what they learned about lightening in the science classroom. This strategy/activity enables the learner to consciously move back and forth between the everyday world and the world of science: "switching terminology explicitly, switching language frameworks and conventions explicitly, switching conceptualizations explicitly" (Jegede and Aikenhead 1999: 57). The teacher is able to assess learners' recordings and navigate his/her own changing roles of *tour guide* and *travel agent* so as to facilitate learners' border crossings.

Conclusion

In conclusion, this article argues that much of Jegede's work and his thesis of collateral learning remains focused on the representational aspects of knowledge, in the sense that Western science and indigenous knowledge are seen as disparate. In the article the author argued that, although science is representation and that it is useful to distinguish between Western science and indigenous (at a conceptual level) knowledge, it is also important for science to be viewed as performance. When the performative side of science is emphasized, then it is understood as a situated activity which connects people, sites and skills: science is locally produced through processes of negotiation based on the social organization of trust and not empirical verification/falsification. Viewed in this way, it is possible to compare seemingly disparate knowledge traditions more equitably and to work with both. *Science as performance* provides the basis for secured collateral learning, and as such the basis for effective science education in (South) Africa. In this instance, the focus should be on doing science – on science as an activity (how it is performed). Viewing *science as performance* shifts the angle of vision on the problem of cognitive dissonance in science classrooms.

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