

Crossing boundarised epistemologies in science education: The affordances of indigenous knowledge

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Good evening, ladies and gentlemen, and thank you for your esteemed presence here tonight. In this inaugural lecture, my central argument is that, by including indigenous (scientific) knowledge in the school curriculum, and by utilising the processes of science in doing so, we could see worthwhile learning effects in the science classroom. The counter argument of cynics might be that many modern urban young people do not have an indigenous knowledge base - a valid point that illustrates why more attention should be devoted to harnessing this often orally transmitted knowledge, before it is lost forever.

Here is the roadmap for the journey of my talk tonight:

1. Introduction: South Africa's dismal performance in science education
2. How the incorporation of indigenous knowledge in the school curriculum could make science more accessible to and relevant for learners
3. Where it all started for me: In the Hantam, with the KhoiSan people
4. Embodied, situated and distributed cognition: the integrated epistemological base of this work
5. The affordances of indigenous knowledge in the science classroom through a Cultural-Historical Activity Theory (CHAT) lens of learning and doing
6. Indigenous knowledge in the 21st Century, and my research agenda.

Proloog: Op 'n Afrikaanse noot...

Benewens ons reis in die natuurwetenskappe onderrig vanaand, neem ek u ook op 'n virtuele reis na 'n baie besondere deel van Suid-Afrika, naamlik die Hantam, en aangrensende Namakwaland en Sederberge, in die Noord-Kaap. Tydens my

etnobotaniese navorsing in hierdie wêreld het ek sterk onder die indruk gekom van die pragtige Afrikaans wat hier gepraat word, en dat dit 'n studie op sy eie verwerdig. Die uitdrukking vir as mens baie kwaad is, en “*voel soos moer-vloek en klipgooi*”, het sy oorsprong in die Hantam. Dit is ook die wêreld van die Riel, waarvan ek graag vir u 'n videogreep wil wys.

1. Introduction: South Africa's dismal performance in science education

In order to be a global player in the world economy, South Africa needs innovative, creative scientists, but this means that science education in the country should be greatly improved. Our learners' performance in TIMSS leaves much to be desired. Various reasons could be provided for the poor performance of South Africa in science education. The Centre for Development and Enterprise, in their 2011 report '*Value in the classroom: The quantity and quality of South Africa's teachers*', makes it clear that our teachers are often poorly trained. Teachers' under-developed pedagogical content knowledge is in my opinion one of the major reasons for underperformance in the science arena. The Centre for Development and Enterprise (2011) refers to the 2007 McKinsey study that clearly highlights that no schooling system can rise above the limits imposed by the quality of its teachers. Literature also refers to the lack of teaching resources in our schools that prevent meaningful inquiry, and laboratory-based learning to take place. Another problem is the very comprehensive Curriculum and Assessment Policy Statement (CAPS) curriculum, which favors transmission-mode teaching, at the expense of inquiry learning (De Beer & Ramnarain, 2012).

We often want to fix the problems by spending large sums of money on interventions targeting FET science education. The wonderful research that is being done in the Childhood Education Flagship programme on the UJ Soweto campus reminds us that we need to focus our efforts more on foundation phase teaching, and the science concept development of young children. Unfortunately time does not allow us to discuss this tonight, but I would like to invite you to, during the reception, talk to Prof Elbie Henning, Mr Francois Naude, and a collaborator from Germany, Prof Annemarie Fritz-Stratman, who is also here tonight.

In my opinion, a reason that is often overlooked, is the fact that the affective domain of human thinking and reasoning is marginalised in science education. By making

science more interesting and more relevant for learners, we might see improved performance. I have witnessed this done at the University of Helsinki in science education, and it is evident of what interest and motivation can do for learning. My argument here is that indigenous knowledge could serve as a very good entry point into the abstract world of science. Recent research in neuroscience (Dubinsky, Roehrig & Varma, 2013) shows us that experiences with an emotional stamp become committed to memory. By linking science to the everyday experiences of learners in the environments where they live, might result in more affective engagement, and eventually more meaningful learning. This is, of course, not a new argument in pedagogy, but with neuroscience evidence comes a renewed legitimacy.

2. How the incorporation of indigenous knowledge in the school curriculum could make science more accessible and relevant for learners

We often forget that learners do not enter the science classrooms as tabula rasa, and that they often have very relevant indigenous and often very personalized knowledge related to curriculum themes. I would like to illustrate this with four examples.

My first example comes from **chemistry**. Traditional leather tanning could serve as a very good way of introducing endothermic reactions in the classroom. Traditionally calcium powder was obtained by grinding the bones of cattle, and adding some potash to it. Next, bird dung was added to the mixture, and applied to the soaked skins. The bird droppings are rich in uric acid, which lowered the pH, and this enhanced the denaturation of proteins, which again acted as catalyst for an endothermic reaction with water molecules (Zaruwa & Kwahe, 2014). Traditional leather tanning could therefore serve as a very good introduction to endothermic reactions.

The second example applies to **technology**, and has been taken from Namaqualand, where the traditional mat house may sometimes still be seen. Van der Merwe (1945) gives an excellent description of the construction methods. The concept of “house” or “dwelling” acquires a deeper and more holistic meaning when one considers the sophisticated nature and efficacy of this construction. In the desert environment, it is heat, rather than cold, which presents the greatest challenge, with

the additional complication that a nomadic lifestyle requires mobility. The lightweight reeds (species of *Cyperus*) of the mats covering the mat house expand when they get wet and thus create a waterproof shelter when it rains. In warm sunshine, the reeds shrink again and cause slits in-between through which air can move freely to keep the house cool. The traditional positioning of the house with its narrow ends facing north and south ensures effective protection against wind. Not only is this design highly innovative from a scientific perspective, but it is also in total harmony with nature because it leaves hardly any carbon footprint and represents optimal utilization of energy.

Another technology example, takes us to the Blombos caves, 300 kilometers east of Cape Town, near Riversdale and Stilbaai. Artefacts from these caves indicate that its inhabitants possessed advanced skills to manufacture jewelry and cosmetic products. They had the ability to produce ochre, by grinding iron oxide, and mixing it with animal fat and charcoal (Emeagwali, 2014).

Our third example comes from **ethno-mathematics**. Knijnik & Wanderer (2004) explain how Portuguese tiles are used to teach isometric shapes in the mathematics classroom in Brazil. In South Africa, with its rich cultural practices and African music, wonderful opportunities exist to use such artefacts in teaching mathematics, e.g. Ndebele artwork to teach geometric patterns.

I limit examples to merely four, and the last example is from the **life sciences**. In the life sciences curriculum, the harmful effects of chemical pesticides are dealt with. Indigenous knowledge holders in the Giyani district in Limpopo have an environmental friendly solution. The local people of the Giyani district have been using the plant *Lippia javanica* as an insect repellent for decades. The CSIR, in conjunction with the local community in Giyani, has registered a patent on the use of *Lippia javanica* as insect repellent. Clinical tests on the widely used citronella oil as a mosquito repellent showed a success rate of 40%, while the oils in *Lippia javanica* seems to be 95% effective (Mothwa, 2011).

Before I continue, I would like to venture into definitions of **indigenous knowledge**. Senanayake, 2006, describes it as “*a way of knowing and doing that local people developed through the ages whilst busy with their everyday activities*”.

Jones and Hunter (2003) and Michie (2000) list the following characteristics of indigenous knowledge:

- Based on experience
- Often tested over centuries of use
- Developed collective data base of observable knowledge
- Adapted to local culture and environment
- Dynamic and changing: a living knowledge base
- Application of problem solving
- Oral transmission sometimes encapsulated in metaphor
- Not possible to separate IK from ethics, spirituality, metaphysics, ceremony and social order
- Bridging the science of theory with the science of practice
- A holistic (IK) versus a reductionist (western science) approach
- An ecologically based approach
- Contextualized versus decontextualised science

3. Where it all started for me: Ethnobotanical surveys in the Hantam, and working with the descendants of the KhoiSan

Now I get to my own journey. In 2008 I embarked on a MSc study with Prof Ben-Erik van Wyk, recording the indigenous plant use of the descendants of the KhoiSan people in the Agter-Hantam. We worked with the so-called “*bossie dokters*” (traditional healers) first, and later on with the general public. In my engagement with these “bossie dokters”, I quickly realised that many of these traditional healers actually follow the so-called “scientific method” that is advocated in the school curriculum, namely making observations, formulating hypotheses, making predictions, deciding upon a suitable method for experimentation, recording results and analysing it. A very good example is ***Sutherlandia frutescens*** (the so-called cancer bush) - an important medicinal plant in South Africa. Researchers have realised that this indigenous shrub common in South Africa has potent medical qualities that were known in early times by the Khoi, San and AmaZulu healers. Early people have observed that people suffering from cancer responded well to extracts made from this plant. They hypothesised that *Sutherlandia frutescens* may

assist cancer patients, since there are active ingredients in this plant that assist the immune system to fight disease. Recent research has shown that the shrub contains an amino acid which fights depression, pinitol which helps patients to gain weight, and canavanine which is successful in treating retroviruses (Van Wyk, 2008). It is used to treat Aids patients today. Although it does not cure Aids, it definitely helps people with Aids to enjoy a better quality of life. This is an interesting example of how modern science is giving status to the work of traditional healers.

South Africa is one of the global hotspots of both biological and ethnic diversity. Southern Africa is rich in angiosperm species (21,817), and Van Wyk and Gericke (2005) estimate that about 3,000 medicinal plants are regularly used in South Africa. Ethnobotany is defined by Balick and Cox (1996) as “the study of the relationships between plants and people”.

But why should we engage with such an ethnobotanical approach? There are two reasons- an economic perspective and a curriculum-driven agenda. The economic importance of plants cannot be over emphasized. Shelly (2009) refers to studies which indicate that between 25% to 57% of prescription drugs sold in the US or worldwide have at least one active compound that is derived or patterned after compounds isolated from natural products. Table 1 provides information on drugs that were discovered from ethnobotanical leads.

Table 1. Examples of drugs discovered from ethnobotanical leads (Balick & Cox, 1996)

Drug	Medical use	Plant species	Family
Aspirin	Analgesic, inflammation	<i>Filipendula ulmaria</i>	Rosaceae
Atropine	Ophthalmology	<i>Atropa belladonna</i>	Solanaceae
Camphor	Rheumatic pain	<i>Cinnamomum camphora</i>	Lauraceae
Morphine	Analgesic	<i>Papaver somniferum</i>	Papaveraceae
Quinine	Malaria prophylaxis	<i>Cinchona pubescens</i>	Rubiaceae

Reserpine	Hypertension	<i>Rauvolfia serpentina</i>	Apocynaceae
Vinblastine	Hodgkin's disease	<i>Catharanthus roseus</i>	Apocynaceae

The Khoikhoi herdsman and San hunter-gatherers are collectively referred to as the KhoiSan people (Schapera, 1930). The KhoiSan could also be viewed the inventors of aromatherapy- not the French! The KhoiSan people in the Hantam mountains used to rub their bodies with fats and powdered aromatic bushes and perfumed plants.

Our survey was conducted in the Agter–Hantam, in the district of Calvinia in the Northern Cape Province of South Africa. We had two hypotheses that guided the investigation. The first hypothesis was that the indigenous knowledge relating to the ethnobotany of the Hantam is poorly recorded and incompletely documented. The second hypothesis was that there is an erosion of indigenous knowledge regarding plant use in younger generations. We were introduced to Mr Jan Baadjies, a traditional healer ('*bossiedokter*'), and subsequently to his family and friends, who collectively represent a substantial part of the indigenous community of the Agter–Hantam.

During phase one, field survey work was conducted to interview local people of KhoiSan descent. Interviews were conducted in Afrikaans (the researchers and participants were from the same language and cultural group). Ethical conduct and equitable relationships were ensured by following the principles contained in the Code of Ethics of the International Society of Ethnobiology (Crouch et al., 2008). A rapid appraisal methodology was followed (Martin, 1995) and practically all of the useful plants of the area were identified during excursions on several farms. Photographs were taken of all the species and plant material was collected (with permission from the landowners) for herbarium voucher specimens. This phase ended with a qualitative assessment, i.e. a list of all the species and their uses.

During phase two (November 2009) we used a rigorous and practical method, the so-called **Matrix Method**, that we introduced in an article in the *South African*

Journal of Botany (De Beer & Van Wyk, 2011). This newly devised quantitative method was used to rapidly quantify the ethnobotanical knowledge of the 16 participants. The participants, all descendants of the KhoiSan people and of different ages, were shown a collection of 64 “images”, comprising herbarium specimens. An uncomplicated instrument (questionnaire) was used to capture answers to the following questions: (1) Does the person know the plant?; (2) Can the person recall a name for the plant?; (3) Can the person recall any uses for the plant (as food, medicinal or for other practical applications)?

The next step was to enter the data into a matrix of participants against species. By adding the scores for each participant, a quantitative measure of his or her knowledge of useful plants is obtained. We express each participant's ethnobotanical knowledge as a fraction (ratio) of the maximum possible score. The value of this “Ethnobotanical Knowledge Index” (EKI) thus varies between 0 and 1. For example, the highest EKI in this study was 0.93 (as expected, for the most knowledgeable participant, Jan Baadjies).

We also wanted an indication of the importance or popularity of each species, as measured by the number of participants who knows the plant and its uses. We express this “Species Popularity Index” (SPI) as a fraction (ratio) of the maximum possible score of 96, obtained by multiplying the number of participants (16) with the maximum score for each species (6). For example, the highest SPI in this study was 1.00 for *Punica granatum* L. (a popular, non-indigenous, cultivated fruit tree that also has traditional medicinal uses), followed by 0.97 for *Aloe microstigma* Salm-Dyck and 0.94 for the popular veld food, *Hoodia gordonii* (Masson) Sweet ex Decne.

The main advantages and unique features of the new Matrix method are (De Beer & Van Wyk 2011): (1) It provides comparative quantitative data of indigenous plant use (across all categories of utilisation), allowing for future comparisons within and between different communities (e.g. average EKI-values) and between the same plant species in different communities (e.g. average SPI-values); (2) The use of images in combination with specimens makes the study independent of flowering season and the need to study the plants in situ. The most knowledgeable

participants are often old and frail and are not able to walk long distances; (3) The fact that all species are shown to all participants excludes the possibility of false negative results.

The new records of indigenous plant use revealed by this study show that the ethnobotany of the Hantam was incompletely recorded and that there is an urgent need to document this wealth of traditional knowledge in other parts of southern Africa, before it is lost forever. Previously unpublished information on indigenous plant use revealed in this study includes 14 new species records of useful plants, 20 new vernacular names not recorded in literature and 99 new uses for 46 of the plant species.

I will now briefly highlight two of the interesting records of plants in the Hantam.

The *ghaap* or *ghoba* (***Hoodia gordonii***) is a popular food item used locally to suppress hunger and thirst and also to treat stomach pain. The appetite-suppressant properties of the plant have been studied scientifically and are ascribed to a chemical compound in the plant known as P57 (Van Heerden, 2004). This plant has become internationally famous as potential anti-obesity drug. The economic implications are huge as the current market potential for dietary control of obesity is billions of US Dollars per annum in the USA. *Hoodia gordonii* provides an interesting example of some of the ethical issues encountered in science. The earliest people in South Africa, the Khoi and San, used it as an edible plant, and the fleshy stem provided the necessary water in a very dry part of South Africa. Research undertaken by the Council for Scientific and Industrial Research (CSIR) in South Africa shows that this plant, with an active ingredient named P57, is an effective appetite suppressant. In the late 1990s, the American firm Pfizer was given the rights to develop *Hoodia* tablets as a commercial undertaking. However, questions were asked about the intellectual property rights of the indigenous (San) people, who have used this plant for many decades or perhaps even centuries. The CSIR therefore signed an agreement with a particular San group in the Kalahari, whereby this San group received royalties from the sales of this plant product. However, this created problems as only one San community was acknowledged and the plant is widespread in the dry areas of South Africa. This might be one of the reasons why Pfizer announced that it will no longer develop the commercial use of *Hoodia*,

although restructuring of the company was given as official reason for withdrawal from the project.

Our research in the Hantam also provided insight in the origin of the name 'Hantam'. Of special interest are the names *aree* (for *Pelargonium carnosum*) and *wilde aree* (for *P. antidysentericum*). The only original record of this vernacular name is in the "Dagh Register" of Simon van der Stel's Namaqualand expedition (Van der Stel, 1685), where it is listed as the Griqua name for two species of *Pelargonium* (the Nama equivalent is given as *Heyntame*). It is therefore suggested that the name "Hantam" is derived from the Nama generic name for *Pelargonium*, a genus which is well represented (and commonly used) in the region around the Hantam Mountain.

Transferring the field work to the Life Sciences classroom

I developed a short learning programme for life sciences teachers on how to incorporate indigenous knowledge in the classroom, using the processes of science. This intervention (a three-day programme) focuses on processes and methodology, rather than on content. I wanted to simplify the Matrix method, and introduce anti-microbial tests that could be done in relatively under-equipped school classrooms. The short learning programme starts with a visit to the muthi market, where teachers can interview traditional healers about some of the medicinal plants. Some of these plants are purchased, and back in the lab, the teachers engage with how these medicinal claims can be tested. Teachers are asked to formulate hypotheses, and to develop experimental procedures that could be followed in a school laboratory.

Whereas certain chemicals in the plant may have anti-microbial activity, other chemicals may be toxic. We therefore introduced a simple chromatography procedure in our course, to demonstrate to the teachers how chemicals in plant materials can be separated. Simple chromatography can be done on a shoestring in the laboratory. As enrichment, teachers are also referred to modern techniques used in laboratories today, such as thin-layer chromatography (TLC), liquid chromatography coupled with mass spectrometry (LC-MS) or high-performance liquid chromatography (HPLC).

A very simple way of determining the susceptibility of a micro-organism to an antimicrobial substance (present in the plant material), is to use a microbe-seeded agar plate and to allow the chemical substance(s) in the plant to diffuse into the agar medium (Mitchell & Cater, 2000). This technique is known as the **Kirby-Bauer technique**. A filter disk impregnated with the agent is applied to the seeded agar surface. As the substance diffuses from the filter paper into the agar, the concentration decreases. At a particular distance from each disk, the antimicrobial agent is diluted to a point that it no longer inhibits microbial growth. The effectiveness of a particular antimicrobial agent results in the production of growth-inhibition zones. These appear as clear halos surrounding the disk (De Beer & Whitlock, 2009).

Teachers are also shown how learners can become engaged in ethnobotanical projects in the classroom, and how herbarium voucher specimens could be prepared by the learners.

During the programme, teachers are also encouraged to plan lessons in other topics as well, including indigenous knowledge. I would like to illustrate this with one example, namely **karrikins and seed germination** (De Beer, 2012). It is widely recognised by plant physiologists that forest fires have the ability to stimulate the germination of seeds. In the more Mediterranean biomes (e.g. the fynbos vegetation in South Africa) fire is essential for some plant species' seeds to germinate.

Indigenous people also knew this, e.g. the **Noongar people**, the native inhabitants of Western Australia. Research shows us that chemicals in the smoke are actually the cause for such seed germination. Smoke is a complex mixture of thousands of different compounds, but Flematti and his co-workers (2004) discovered the chemical responsible for this effect. Butenolide derivatives known as karrikins are plant growth regulators found in the smoke of burning plant material. These karrikins are formed from burning cellulose, the molecule that makes up the cell walls in plants. Recently a highly active butenolide, 3-methyl-2H-furo[2,3-c]pyran-2-one, also known as KAR₁, was isolated from smoke as a stable and volatile growth stimulant (Van Staden, 2010). Karrikins were named after "karrik", which means "smoke" in the Noongar language. I published an article in *The American Biology Teacher*, on how school learners could do an investigation to actually determine the influence of karrikins on seed germination, by following science-on-a-shoestring approaches.

Lazy Housewife beans (*Phaseolus vulgaris*) were used in my investigation. The beans in the control were not exposed to smoke; the beans in the experimental groups were exposed to smoke (from burning charcoal) for 30 minutes. After exposure to the smoke, seeds were placed between two wet pieces of cotton wool, and left in a cool place (but exposed to daylight). Once germination takes place, students should measure the length of the shoots, or determine the mass of the germinating seeds. Seeds exposed to smoke germinated better than seeds in the control (not exposed to smoke) (De Beer, 2012).

The research agenda linked with this short learning programme: Teachers' view of the nature of natural sciences, and the nature of indigenous knowledge systems

Abd-El-Khalick, Bell and Lederman (1998) are of the opinion that a person who has a sound concept of the nature of natural science will understand that this science is tentative (subject to change), empirically grounded (conclusions based on observations); subjective; partially the product of human conclusion, imagination and creativity and that it has a social and cultural context. However, research has shown that many teachers have naive and outdated views of the nature of science (Galagher, 1991; Lederman, 1992; McComas, 1998, De Beer & Ramnarain, 2012). If we expect the life sciences teacher to present various knowledge systems in juxtaposition to learners as possible explanations of natural-scientific phenomena, it is necessary to equip teachers with the understanding of values needed to compare the systems (Dekkers & Mnisi, 2003).

Unfortunately, there are many teachers who still regard indigenous knowledge (particularly concerning traditional healing) as magic, which is light years removed from science. This is sad - in a country that is suffering owing to the HIV/ AIDS virus, very high levels of unemployment and a situation where South Africa is struggling to be internationally competitive owing to insufficient numbers of trained scientists, indigenous knowledge (and particularly ethnobotany) opens many doors to prospective scientists and entrepreneurs.

A PhD student of mine, Annelize Cronje, developed a framework for the nature of indigenous knowledge- an aspect that should receive attention in pre-service and in-

service teacher education. Table 2 compares the nature of indigenous knowledge to the nature of science, and it is clear that there is overlap.

Table 2

Nature of indigenous knowledge framework in relation to the nature of science framework (Cronje, 2015)

Nature of Indigenous knowledge (NOIK)	Nature of Science (NOS)
• <i>Empirical and metaphysical NOIK</i> Nature is real, partly or generally tested and observed. Needs-based experimentation. The universe is orderly, metaphysical and partly predictable. • <i>Resilient yet tentative NOIK</i> IK has withstood the test of time, but is constantly changing as tradition; it is fluid and transformative – linked to people’s experiences. It must be kept in mind that the elder’s repository of ways of knowing is truth and not to be challenged. • <i>Inferential yet intuitive NOIK</i> Facts are both tested and experimental observations made. Events have both natural and unnatural causes; metaphysical dimensions are important. • <i>Creative and mythical NOIK</i> Observations and experimenting are not the only sources of ways of knowing. Human creativity, imagination and myths also play a role. • <i>Subjectivity of NOIK</i> Indigenous ways of knowing is based on cosmology and interwoven with culture and the spiritual. The elders can be influenced by prior ways of knowing and beliefs. • <i>Social, collaborative and cultural</i>	• <i>Empirical NOS:</i> Nature is real, observable and testable. The universe is orderly and predictable. • <i>Tentative NOS</i> Science is subject to change and not absolute and certain. It is challengeable by all. • <i>Inferential NOS</i> There is a clear distinction between observations made of nature and deductions or conclusions (inferences) made from observations to explain the causes. All events have natural causes. • <i>Creative NOS</i> Observations and experiments are not the only sources of scientific knowledge. Human creativity and imagination also play a role. • <i>Subjectivity(theory-laden) of NOS</i> Scientists strive to be objective and culture free, but as human beings they are subjective and influenced by theoretical and disciplinary commitments, prior knowledge and beliefs. • <i>Social and cultural NOS</i>

NOIK

Indigenous knowledge is situated in cultural tradition and within a certain historical-political context. It is the consequence of activities connected to everyday life in the natural environment of a group of people. It does not focus on the individual, but on the group and sharing. Indigenous knowledge is locally rooted and ecologically based. It is generated at a specific place by people of that place. Generalizations are relative within a certain context and can be shared amongst communities and beyond.

- *Wisdom in action and NOIK*
Indigenous knowledge is generated by practical engagement in everyday life through trial and error experiences. Repetition and ceremonies are methods to aid retention and reinforce ideas. New ideas are rigorously tested in the “laboratory of survival” (Senanyake, 2006:87).
- *Functional application and NOIK*
Indigenous knowledge is concerned with what and why things happen in nature, but also with what ought to happen. Emphasis is on practical or functional application and skills. Indigenous knowledge is concerned with the everyday lives of people rather than facts, theories and laws.
- *Holistic approach of IK*
Indigenous knowledge is “a conglomeration of knowledge systems” (Ongunniyi, 2007: 965) including science, religion, psychology, religion and other fields. Problems and issues are solved in a holistic manner addressing all the smaller parts with no boundaries with the metaphysical world.

Scientists try to be objective, but science is a human endeavor and is therefore affected by a social and cultural milieu. Scientists do sometimes work individually. Science is generated at a specific place and thus local, but generalised scientific laws and theories have universal applications

- *Methods and NOS*
Science knowledge is not generated by a single step-by-step universal method. Scientists use a variety of methods to solve problems and test theories. These methods are usually done in laboratories.
- *Theories and laws and NOS*
Scientists use theories and laws to explain what, why and how things happen in nature. A scientific law describes what happens, while a theory explains why and how things happen. Scientific laws are causal, rational and logic.
- *Reductionist approach of NOS*
Complex phenomena can be broken down into small parts and analysed. The part to whole method is used.

The views on the nature of science (VNOIK) questionnaire

We required an instrument to use as pre- and post-questionnaires to find out, by way of self-reporting, if the intervention did have an influence on science teachers' views of indigenous knowledge. We could not find a suitable instrument and decided to develop our own instrument, grounded in the nature of indigenous knowledge framework discussed in Table 2 and based on the views of the nature of science questionnaire developed by Lederman et al (2002). The views on the nature of indigenous knowledge questionnaire (VNOIK) stated in Figure 1 consist of ten open-ended questions.

Figure 1: The VNOIK questionnaire (Cronje, 2015)

VNOIK Questionnaire

Instructions:

- Please answer each of the following questions. Include relevant examples whenever possible.
- There is no “right” or “wrong” answer to the questions. We are only interested in **your opinion** on a number of issues regarding indigenous knowledge.

1. In your view what is indigenous (or traditional) knowledge?

What makes indigenous knowledge different from other types of knowledge systems (such as western knowledge)?

2. Practitioners of indigenous knowledge (e.g. elders, herbalists, traditional healers) observe nature to generate knowledge. Do they do experiments and tests in order to verify or validate this knowledge?

- If yes, explain how they test or validate their knowledge
- If no, explain why not

3. Practitioners of indigenous knowledge observe nature and give explanations about their observations. Elders in a community can, for example, explain where lightning comes from. Do the elders always use natural causes to explain their observations such as lightning, or do they sometimes include supernatural causes in their explanations?

- If they only use natural causes, explain why and give examples of some of the causes.
- If they sometimes use supernatural causes, explain why and give examples of some of the causes.

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4. Indigenous knowledge is transferred from one generation to the next over many decades and centuries. Does this knowledge stay the same or does it change over time?
 - If yes, explain why it stays the same
 - If no, explain the causes of such changes
 5. *Hoodia gordinii* is a plant that was used by Khoi-San hunters to suppress their hunger and thirst when they went on hunting expeditions. How **do you think** the Khoi-San people come to know that this particular plant has these properties?
 6. Sustainable development is an emerging concept that includes topics such as hunger, poverty and underdevelopment. Globally governments and organisations struggle to find solutions for these important issues. **Do you think** indigenous knowledge can be used to alleviate some of these problems?
 - If you say yes, please explain why and how indigenous knowledge can be used to solve these problems
 - If you say no, please explain why it cannot be used to solve these problems
 7. An athlete regularly competing in marathons struggles with pain in his legs during the last part of a marathon and can sometimes not complete a marathon due to this. The athlete decides to consult a traditional healer to determine why his legs pain during the last part of a marathon.
 - What methods **do you think** the traditional healer will apply to diagnose the problem when consulting with the athlete?
 - What possible treatment or advice **do you think** he will give the athlete?
 8. Myths are stories that are told in different cultures by elders from one generation to the other. Do you think myths and rituals play any important role in indigenous knowledge systems? Explain your answer with examples if possible.
 9. Some claim that indigenous knowledge is infused with social and cultural values. That is, indigenous knowledge reflects the social and political values, philosophical assumptions, and intellectual norms of the specific culture in which it is practiced. Indigenous knowledge is thus generated locally and can only be used in a specific area. It cannot be used universally in other contexts or globally to solve different problems.
 - Explain how indigenous knowledge reflects the social and cultural values of a local community.
 - Do you believe that indigenous knowledge can only be used in a specific area or do you believe it can be used in other areas or globally to solve problems? Explain your answers with examples.
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10. Indigenous knowledge is passed from one generation to the other by elders. The elders are deemed very important and some people believe their ways of knowing (knowledge) is truth and cannot be challenged. Does this mean that current practitioners of indigenous knowledge must use this knowledge exactly as it was passed on to them, or can they use their creativity and imagination to modify the indigenous knowledge to solve current problems?
- If you say yes and believe that indigenous knowledge practitioners cannot change this knowledge, explain why. Use examples if possible.
 - If you believe that indigenous knowledge practitioners can change and modify his knowledge, explain why. Use examples if possible.
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A panel of experts examined the initial questionnaire to ensure content validity and face value. The suggestions of the panel were applied and the questionnaires were modified accordingly.

The main research questions we wanted to address were: What are the views of science teachers on indigenous knowledge and what is the effect on an intervention in changing the (self-reported) perceptions of the science teachers on indigenous knowledge? We sampled purposefully for optimal difference in educational contexts. The VNOIK questionnaire explained in figure 1 was used as instrument. The intervention and questionnaires were administered to three cohorts of science teachers, in Johannesburg, Mafikeng and in Mayflower in Mpumalanga.

To ensure that the responses of the participants were coded and evaluated consistently, a rubric with possible responses and a rating scale was developed using different sources of literature reporting on indigenous knowledge as well as the answers from the expert group. According to the rubric the responses to each question were coded in categories as an informed view, a partially informed view and an uninformed view on indigenous knowledge. The results of the coded questionnaires are summarised in Table 3.

Table 3: Summary of results of pre- and post VNOIK questionnaires of participants

View of participants	Percentage of participants before the intervention	Percentage of participants after the intervention
Uninformed view	3.8%	0%
Partially informed view	80.8%	53.8%
Informed view	15.4%	46.2%

The results indicate that some of the science teachers reported that they had adjusted their views on indigenous knowledge during the period of the intervention. (We do not know if their amended view will hold and a follow-up study would show that). There was an increase of 30.8 % among teachers, who after the intervention had a more nuanced view of indigenous knowledge. The teachers started to respond to indigenous knowledge as a source of science knowledge. Literature informs us that a systemic longitudinal approach to professional development involving communities of practice is needed for internalisation to occur (Buysse, Winton & Rous, 2008; Steyn, 2010). We agree with this and recommend that this type of intervention be developed into different themes over an extended period of time within communities of practice.

4. Embodied, situated and distributed cognition

The viewpoint of embodied cognition is that cognitive processes are deeply rooted in the body's interactions with the world (Wilson, 2002). Learners develop their worldviews based on their (situated) engagement with people and the environment. Such cultural knowledge is co-constructed (and therefore distributed in the community). This provides a very good entry into the abstract world of science.

IKS are part of a human being's lived experiences, whether it is part of the body ("embodied cognition"), or direct environment ("situated cognition") or his/her social interaction with people ("distributed cognition") (Wilson, 2002, p. 625). According to Wilson (2002) embodied cognition refers to the intellectual processes deeply rooted in a person's (entire) bodily interaction with the world; situated cognition indicates the

cognitive activity happening in the context of a real life environment; and distributed cognition denotes the spreading of cognition throughout the overall interaction situation, including the mind, body and environment. (See the recent article on the “noncognitive” and “cognitive” debate in the recent Educational Researcher – Duckworth and Yeager, 2015).

Richard Dawkins (1982: 4-5) asks for a ‘mental flip’ in how we view phenotype. He uses the example of a spider on its web. Through Dawkin’s lens, the spider web is an extension of the spider’s DNA- this DNA codes for the synthesis of specific proteins that manifests in the phenotype (the web). Embodied, situated cognition sees the human brain as the productive interface between body, brain, social and material world (Clark, 2011).

5. Looking at the affordances of indigenous knowledge in the science classroom through a Cultural-Historical Activity Theory (CHAT) lens

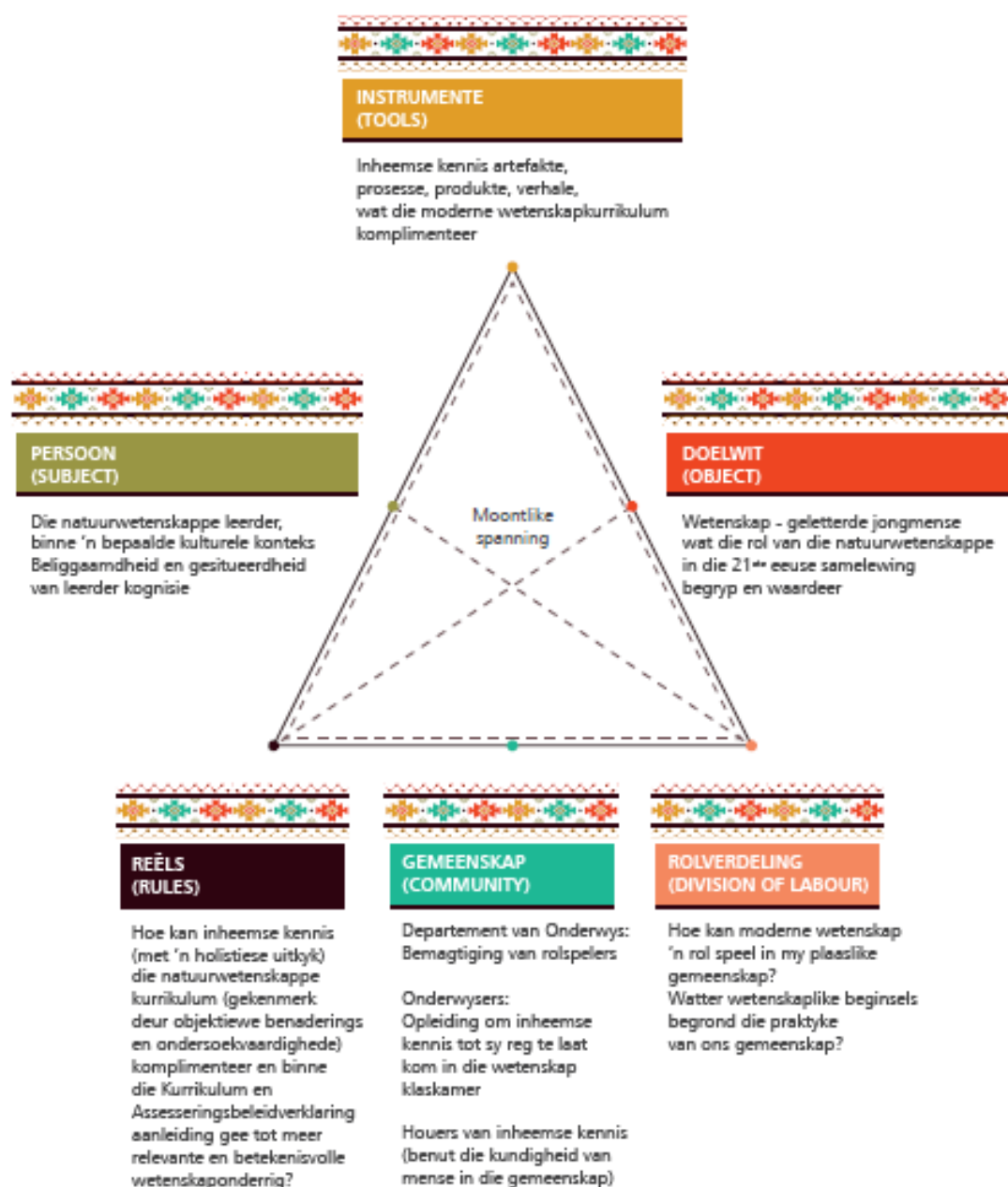
I would now like to provide a theoretical argument for the inclusion of indigenous knowledge in the science classroom, by using Engeström’s (1987) third-generation Cultural-Historical Activity Theory (CHAT) as a lens. Activity theory has its roots in Vygotskian theory. Lev Vygotsky (1978) is well known for, among others, his idea of the construct of the zone of proximal development. Some knowledge a learner can obtain on his own, without scaffolding or mediation- this is referred to as the actual development. Through the mediation of a more competent peer or expert, who could, in our case tonight, either be the teacher in the classroom, or a traditional healer or holder of indigenous knowledge in the community, it is possible for a child to realise his/her potential development. The Zone of Proximal Development is this zone between actual and potential development, that could be bridged by carefully constructed mediation or scaffolding, using semiotic tools.

Engeström has developed third-generation activity theory that could be a very useful lens to identify tensions in an activity system, which is his systems approach to human activity. He refers to this as an activity system. In our work, the system would be the classroom, where we want to incorporate indigenous knowledge in the teaching of the science curriculum. The CHAT lens makes provision for a specific ‘gaze’ into the activity system – looking for an acting subject, an object of activity,

tools and signs used in mediating activity, rules of the system, the community in the system and the division of labour in the system .

One way of utilising the CHAT lens, would be to see the school learner as the subject, an understanding of the role of science in a modern technological society would be the object, and a pedagogy including indigenous knowledge could be one of the tools used. Between these different nodes tensions can be identified, by using CHAT as a research lens.

Figure 2: Third-generation Cultural-Historical Activity Theory



A Masters student of mine, Melida Mothwa, used this research lens to enable such an epistemological gaze to identify such tensions in such a system. I will now just mention the major themes that emerged from this study.

Theme 1: The challenges experienced with the infusion of IK in teaching Life Sciences mostly centres around a lack of teacher pedagogical content knowledge (PCK)

The data revealed that teachers experienced several challenges in relation to the infusion of IK in teaching Life Sciences, which mainly points to the lack of teacher PCK. Traditionally teachers were not trained during their pre-service education to incorporate indigenous knowledge.

Category 1.1: Insufficient training and professional development for the implementation of the curriculum

Category 1.2: Lack of IK-related material resources in school

Category 1.3: Cultural diversity and differences

Teachers might be knowledgeable in terms of their own culture, but do not necessarily know much about IK in other cultures.

Category 1.4: Lack of support systems from the Department of Education

Category 1.5: Lack of pedagogical content knowledge (PCK)

All of the above imply that teachers' under-developed PCK seem to prevent the effective teaching of IK in the Life Sciences classroom. Teachers need relevant pedagogical content knowledge in order to infuse their teaching with IK. A Life Sciences teacher needs *content knowledge*, i.e. know-how of the indigenous knowledge claims of different cultural groups, e.g. plants used for medicinal reasons; *pedagogical knowledge*, i.e. how to effectively structure learning opportunities for learners when exploring IK claims, and *contextual knowledge*, i.e. what the cultural background of the learners are.

Theme 2: The emotional experience of the participants (teachers) in relation to teaching IK in Life Sciences

Category 2.1: Teachers' own negative perceptions of IK

Some teachers are negative about IK, and feel that IK cannot be scientifically proven and that it constitutes “pseudo-science”. Many teachers do not have the know-how to incorporate PCK in a scientific and rigorous way.

Theme 3: A lack of a nuanced understanding of the nature of science, and the nature of indigenous knowledge systems

Many teachers show a lack of understanding of the nature of science, and the nature of indigenous knowledge systems.

We also obtained quantitative data. Questionnaires were sent to schools in the Gauteng and Limpopo provinces in South Africa, and 255 teachers completed and returned questionnaires.

The quantitative data are summarized in Table 4.

Table 4: Teachers’ responses to questions, using a Likert scale, about the implementation of indigenous knowledge in the classroom (n = 255).

	Negate vehemently	Do not agree fully	Agree	Agree wholeheartedly
By referring to indigenous knowledge, learners perceive science as more relevant.	1.7%	11.7%	60.9%	25.7%
The natural sciences explain all natural phenomena perfectly.	7.6%	51.3%	33.5%	7.6%
The importance of indigenous knowledge is exaggerated.	4.5%	64.1%	25.6%	5.8%
There is no connection between indigenous knowledge and modern science.	9.4 %	63.4 %	22.8 %	4.4 %
Indigenous knowledge is often in conflict with modern science.	0.5 %	37.9%	51.4 %	10.2 %

The quantitative data show that life sciences teachers realize the importance of indigenous knowledge, and that they realize that it plays a role in making life sciences more relevant for the learners. A large percentage of the teachers (41.1 %) are of the opinion that natural sciences can fully explain natural phenomena. The majority of the teachers (61.6%) are of the opinion that indigenous knowledge and science are in conflict with each other. An important reason for this view is teachers' deficient knowledge regarding indigenous knowledge.

Why this perceived conflict? The holistic nature of indigenous knowledge

Many teachers point to the fact that metaphysical aspects of indigenous knowledge are a concern. My argument tonight is that we should focus in science on that section of indigenous knowledge that is aligned with the tenets of the nature of science. As shown, medicinal claims of plants can often be tested by using anti-microbial lab protocols. Although there is not necessarily space for metaphysical components within the epistemology of science, it does not mean that science denies its existence. I would like to give one example of yesteryear's "magic" that can actually be explained by science today. Van Wyk and Wink (2003) point out that British indigenous knowledge (the use of limes – *Citrus limon* – by seamen to eliminate the symptoms of scurvy miraculously and apparently through supernatural intervention) could be explained only 200 years later by modern science with the discovery of vitamin C.

The story of the **shadow of the blue hawk** (in Afrikaans: *die skaduwee van die blouvalkie*) was recorded by Van Wyk and Gericke (2000). Traditionally *Dicoma schinzii*, the "*koorsbossie*" is used to treat convulsion or seizures ("*stuipe*") in children. The story, once analysed, is actually an account of how convulsion sickness in children should be treated. In African mythology, birds normally refer to fever. There is actually a lot of scientific merit in this. Whereas the body temperature of humans is 37 degrees Celsius, the body temperature of birds is significantly higher (around 40 degrees Celsius). Convulsions in babies remind of the irregular movements of the blue hawk's wings, when it circles its prey. The reference in the story *that the baby may develop feathers on the arms, refer to the gooseflesh of fever*- one of the symptoms of seizures in babies. This story is actually a narrative

that reminded people who could not read or write, how to treat convulsion sickness in babies.

6. Indigenous knowledge in the 21st century, and my research goals

Indigenous knowledge holds many affordances for both economic development in South Africa, and for science education. There are so many success stories- just think of Rooibos tea, Honeybush tea (*Sceletium* sp), and the commercial Amarula Cream. In terms of science education, the inclusion of indigenous knowledge has affective affordances, and could lead to learners experiencing science education as more relevant.

In terms of my own research goals, I would like to focus on teachers' professional development and self-directed learning, resulting from short intervention programmes where we focus on indigenous knowledge in the formal school curriculum. Our Faculty hosts the Self-Directed Learning research area, and indigenous knowledge is now one of the sub-programmes within SDL. We have been invited to become a member of the Department of Science and Technology/ NRF funded Indigenous Knowledge Centre, and now have access to expertise to develop intervention programmes in other subjects like mathematics, physical sciences, geography and technology. Many research opportunities exist: what transfer take place in the classroom? Do teachers show the agency to overcome obstacles that they might face in the schools, e.g. a lack of resources? Do teachers make use of the blended learning platforms (like eFundi) provided, to improve their pedagogical content knowledge?

I would like to conclude this lecture, with a word of caution. In my opinion, we need to guard against two potential threats:

1. I am not an advocate for pseudo-science. We should introduce indigenous knowledge in a rigorous way in the science classroom, using the processes of science. A number of myths exist in communities, such as that one could win the lottery by eating the eyes of a vulture. Such myths should be exposed in the classroom as ill-informed and harmful practices.
2. Too much of the current research into indigenous knowledge systems today is not rigorous enough, or do not have theoretical foundations that are plausible.

It was our dissatisfaction with the state of ethnobotanical surveys, that lead Prof Ben-Erik van Wyk and me to develop the Matrix method. We should use appropriate research lenses when we embark on this educational research.

We need to look scientifically at the science of local old knowledge. This is not a matter of ideology as much as it is a matter of the archaeologies of knowledge. I propose that IKS be seen as a digging into the knowledge systems that have worked for enduring communities such as the people of the Hantam. Conceptual change and the nurturing of a scientific world view , which is the ideal of science education, include a better understanding of the oral knowledge of cultures and its place in society.

I thank you.

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