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Source: The American Biology Teacher, 71(4) : 209-216

Published By: National Association of Biology Teachers

URL: https://doi.org/10.1662/005.071.0407

ARTICLE

Indigenous Knowledge in the Life Sciences Classroom: Put on Your de Bono Hats!

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The whole world was united in its condemnation of the pre-1994 apartheid regime in South Africa. Apartheid meant that many South Africans were robbed of their democratic voices and cultural identities. In this article, the authors would like to pose the question: Are you guilty of "knowledge apartheid" in your biology classroom? Does every student have a voice in your classroom? Do you respect the various cultural backgrounds of your students, and the indigenous knowledge they bring to the classroom? The development of the *National Science Education Standards* (1996) in the U.S. was guided by several principles, one being that school science reflects the intellectual and cultural traditions that characterize the practice of contemporary science. Also, Teaching Standard A has a subsection that states that a teacher should select science content and adapt and design curricula that meet the interests, knowledge, understanding, abilities and experiences of students (*National Science Education Standards*, 1996). Recent research (Zeidler, Sadler, Simmons & Howes, 2005) also points to the value of a socio-scientific issues (SSI) approach to science teaching. The SSI approach encourages students to consider how science-based issues affect their own lives and to reflect on the moral principles that underpin science. This article gives suggestions on how both the above-mentioned principles can be accommodated in the life science classroom. We do not argue that all indigenous knowledge claims should be accepted, or that they should be seen as science. This article builds on Content Standard G (History and Nature of Science), and that scientific explanations must meet certain criteria. We show how knowledge claims in the field of traditional healing could be scrutinized and subjected to experimental procedures in the classroom (*National Science Education Standards*, 1996).

The Relevance of Science Education Study (ROSE) showed that a very high negative correlation exists between students' perceptions of the relevance of science, and the development index of the country (Sjøberg & Schreiner, 2006). The more developed a country, the more irrelevant students often find the curriculum. A possible reason for this might be that curricula in developed countries subscribe to what Odora Hoppers (2004) calls "cosmopolitan knowledge," anchored in Western philosophies and scientific discoveries that might be alien to some students. This "westernized" focus on biology is often at the expense of indigenous knowledge (IK)–a practice that Odora Hoppers (2004) calls "knowledge apartheid." Though indigenous knowledge is most often marginalized in the biology classroom, it sustains millions of people economically, socially, and spiritually. Even in biology classes where IK is considered, it is often very clinical. Metaphorically one can say that IK included in the classroom is, more often than not, preserved in a formaldehyde solution. In this article we would like to show, based on our designed-based research, how one can include IK in a lively and academically sound way. In our view, many teachers are hesitant to incorporate IK in the classroom out of fear of infecting classroom teaching with pseudoscience. The teaching strategy explained in this article is anchored in "Western science," though it embraces cultural aspects and indigenous knowledge. It gives practical ideas on how one can address the "practice of contemporary science," as described in the *National Science Education Standards* (1996):

> *Science is a way of knowing that is characterized by empirical criteria, logical argument, and skeptical review. Students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture.*[1]

You will need to adapt the activities for your particular situation, tapping into the cultural diversity in your classroom. Examples relevant to the American classroom are provided, though this design-based research was done in South Africa using South African examples. The U.S., like South Africa, has a diverse student population, and a stronger focus on IK might help to bridge the achievement gap.

○ Research Methodology

A design-based methodology was used, in which foundation year students were exposed to a series of laboratory sessions and hands-on activities, exploring indigenous knowledge claims in the field of medicine. These students have passed 12th grade (final year secondary school), but do not meet the entrance requirements for degree studies at a university. They are given the opportunity to do a foundation (or pre-university year), and based on their performance, they can then obtain university entrance. Qualitative data-gathering methods such as conversation, structured and semi-structured interviewing, document analysis, investigator diaries, casual observation, and structured observation were used. Design-based research involves ongoing cycles of inquiry (design, implementation, analysis, and revision). Insights gained from the first time the researchers implemented this intervention resulted in changes in the second round of intervention. In this article, we reflect on the final version of this intervention, which seems to be very effective in addressing higher-order thinking skills, developing a tolerance of other viewpoints, and considering the moral fabric underpinning decisions in the life sciences. This approach will be useful to students in levels 5-8 and levels 9-12 in the life science classroom.

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[1] This article argues for the inclusion of IK in the life science classroom. It does not argue for the promotion of pseudoscience or medical quackery. The description of the practice of contemporary science in the *National Science Education Standards* should guide you in these discussions. Students should critically reflect on these (indigenous) knowledge claims.

We also wrote this article through a critical qualitative research lens. Traditional healing in virtually all its forms was illegal for more than a century in South Africa, but this did not stop people from practicing it. Under provisions of the Suppression of Witchcraft Act of 1957, first introduced in 1895, all forms of divination were outlawed. Divination is at the heart of healing in Africa (Ashforth, 2005). The new democratically-elected government in South Africa is strongly committed in rectifying the situation of traditional healers. Life sciences provide wonderful opportunities to address one of the goals in the *African National Congress's (ANC's) National Health Plan* (1994), which states that "... people have the right of access to traditional practitioners as part of their cultural heritage and belief system." Native Americans (American Indians) traditionally held, and many today still hold, similar views that spiritual health and physical health are inseparable.

Table 1. Aligning the suggested approach to the Content Standards (*National Science Education Standards,* 1996).

Science in personal and social perspectives (Content Standard F)	
Levels 5-8 Personal health Populations, resources and environments Science and technology in society	**Levels 9-12** Personal and community health Natural resources Science and technology in local, national and global challenges
History and nature of science standards (Content Standard G)	
Levels 5-8 Science as a human endeavor Nature of science History of science	**Levels 9-12** Science as a human endeavor Nature of scientific knowledge (esp. that **scientific explanations must meet certain criteria**) Historical perspectives

○ Why Incorporate Indigenous Knowledge (IK) into Life Science Education?

At this stage we should perhaps provide a definition of what is meant by indigenous knowledge. IK is the sum total of the knowledge and skills which people in a particular area possess, and which enable them to get the most out of their natural environment. Jones and Hunter (2003) and Michie (2000) identify the following common themes embedded within IK that are intrinsic to its integration into the science curriculum:

- 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
- Inclusive versus the specialization of knowledge
- Contextualized versus decontextualized science

Why should a biology teacher consider including indigenous knowledge in the classroom? By including indigenous knowledge in the curriculum, the particular social identity of the student is acknowledged. By acknowledging students' particular cultures, science programs can turn learning into a more positive experience for students who are resistant to studying the westernized science curriculum. Cummins and Swain (1986) are of the opinion that the language of science is "cognitively demanding" and "context reduced." The scientific knowledge of indigenous culture, however, is less demanding cognitively than westernized science because it is based in experienced reality, and associated with a vocabulary more accessible to students. Incorporating IK in the biology curriculum will enable students to better understand academic science content while accessing scientific language (Klos, 2006). Illustrations of how the above can be managed in the life science classroom, through a series of classroom activities, follow.

Setting the Scene for Students: Western Medicine versus Traditional Healing

Take the local context into consideration when you plan this series of learning tasks. Do research on some of the traditional healing practices that your students might be aware of. For instance, if you have Indian students in your class, you might want to include Ayurveda as a form of alternative healing. As illustration, we will use South African examples. Most anthropologists place traditional African healers into the following categories:

- Ancestrally-designated diviner or mediator (*isangoma* in Zulu; *igqira* in Xhosa) provides a diagnosis usually through spiritual means.
- Doctor or herbalist (*inyanga* in Zulu; *ixhwele* in Xhosa) works primarily with herbs and other forms of medication and has not been called by the ancestors.

Our point of departure in the classroom is the work of inyangas or herbalists, and we provide students with sufficient scientific evidence for the knowledge claims of these traditional healers. Muthi refers to substances produced by herbalists to heal, cleanse, or strengthen, and often contains various plant materials (Ashforth, 2005).

Dugmore (2007) states that "... history, like time, is round. Sooner or later the wheel turns to remind us to explore the application of ancient discoveries in the modern world. Medicinal plants perfectly illustrate this because they offer one of our most ancient sources of knowledge across the globe. Whether we are studying the indigenous medicinal knowledge of the Koisan people dating back many thousands of years or the medicinal knowledge of early European doctors, it all comes back to plants."

African traditional medicine (ATM) is holistic and attempts to go beyond the boundaries of the physical body into the spiritual (Emeagwali, 2003). This is in contrast to bio-medicine (Western medicine) which views the body mechanistically in terms of individual parts. ATM can be categorized as mind-body medicine. Some common medical principles have emerged over time in various African regions. These include several scientifically-proven techniques and strategies, some of which are culturally specific and of psychological importance. Among the common principles and procedures utilized in ATM are hydrotherapy, heat therapy, spinal manipulation, quarantine, bone-setting, and surgery.

Traditional healers have an unmistakable and crucial role to play in building the health system in South Africa and strengthening and supporting the national response to HIV/AIDS. South Africa has about 23,000 Western medical doctors, and over 300,000 traditional healers. Eighty percent of the population patronizes the latter (Ardell, 2004). However, there are also traditional healers who do injustice to the profession, and students should be made aware that not all traditional healing practices are sound. The International Council for Science (ICSU) has called for criteria to distinguish traditional knowledge from pseudo-science[2] (Bala & Joseph, 2007), and this should be emphasized in your teaching. Due to decades of colonialism, cultural imperialism, and the power of the multi-national pharmaceutical industry,[3] traditional healers and traditional medicines have been marginalized and their value to communities underplayed. There is therefore a need for urgent investment and support of responsible traditional healers and traditional medicine–not only by government, but also by society and the private sector.

The U.S. has a rich cultural heritage that should be showcased. The American continent is a rich source of plant species, and some of these plants were used for medicinal purposes by Native Americans and also by some of the first settlers.

Indigenous Knowledge & Western Science: Is There a Conflict?

Horn (2005) asks the important question of what kind of knowledge natural healers have and how it differs from the knowledge taught and researched in Western universities. This question has a determining influence on the way indigenous African knowledge is perceived in the Western countries, and also on how Western knowledge is used in Africa. Thus it is important to understand how indigenous African people relate to a globalized economy. Africans cannot avoid becoming part of what the west has achieved in the world, without forgetting that they, too, have something to offer from their cultures and knowledge. One needs to arrive at a new integration of IK and that of the rest of the world.

Scientists in South Africa are testing many different plants that seem to have potential for healing illnesses like malaria, TB, and diabetes. Others are being considered for use as immune modulators for liver transplant patients (Horn, 2005). Table 2 gives a number of examples of the ethnobotanical use of plants in the U.S. *Sutherlandia frutescens* is commonly known as the cancer bush. According to a traditional healer, Credo Mutwa, the cancer bush radiates energy and well-being, cleans the blood, is a tonic, combats the symptoms of flu, and can be used to combat cancer and STDs. Researchers have realized that this indigenous shrub common in South Africa has potent medical qualities that were known in early times by the Khoi, San, and Zulu healers. Early people have observed that people suffering from cancer responded well to extracts made from this plant. This has made them hypothesize that *Sutherlandia frutescens* may assist cancer patients, since there are active ingredients in this plant that assist the immune system to fight disease. Recent (Western) research has shown that the shrub contains an amino acid that fights depression, pinitol (which helps patients to gain weight), and canavanine (which is successful in treating retroviruses). 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 (Bowie et al., 2005).

A researcher at the University of Pretoria, Emmanuel Tshikalange (2006), studied the success rate of traditional healers in treating sexually transmitted diseases (STDs). His findings showed that traditional healers are indeed very successful in treating patients with STDs. He has done a chemical analysis of some of the plants used by traditional healers, and identified anti-microbial agents in most of these plants (Tshikalange, 2006).

Drawing on the Syntactical Nature of Life Sciences: Hypothetical Deductive Methods of Science

The syntactical nature of science refers to the processes of science, or, as described in the *National Science Education Standards* (1996), *"... a way of knowing that is characterized by empirical data, logical argument, and skeptical review."* The approach followed in our classrooms during this design-based research focused on the syntactical nature of the life sciences, and a heuristic strategy was followed in which students were introduced to the hypothetical deductive methods of science. The following steps were dealt with in the classroom setting:

- How do researchers (including in our context, traditional healers) formulate hypotheses based on observations?
- How do they plan an experimental design?
- How do they identify and collect the plant *Sutherlandia frutescens*, the cancer bush? You are advised to use any plant with medicinal properties in your classroom. Refer to Table 2 for possible examples. The safest option is probably to use one of the following herbs: *Achillea millefolium* (yarrow), *Allium sativum* (garlic), *Convallaria majalis* (lily of the valley), *Crataegus laevigata* (hawthorn), *Cynara scolymus* (globe artichoke), *Gingko biloba,* or *Viburnum opulus* (cramp bark). Hoareau and DaSilva (1999) indicate that research shows that the non-nutrient phytochemicals in these plants are increasingly being recognized as potential health promoters in reducing the risks of cardiovascular disease and atherosclerosis.
- How is pharmacological testing done, and alkaloids extracted? In the life sciences classroom, a simple chromotagraphical technique could be followed, using a science-on-a-shoestring approach.
- How do bioassay procedures enable scientists to assess the chemical activity of the plant extract(s)?
- How are clinical trials planned?
- How are drug applications and patents handled?

The article also sheds light on how this approach will embrace the affective domain, and how a learning outcome (such as emphasizing the role of science and technology in society) can be addressed.

[2] The ICSU argues that science has a higher degree of "systematicity" than pseudo-science. There are six aspects to this systematic character ((Bala & Joseph, 2007): how science describes, how science explains, how science establishes knowledge claims, how it expands knowledge, how it represents the world, and the ideal of completeness that science pursues.

[3] An interesting topic for discussion can be bio-piracy. Do people possessing indigenous knowledge have intellectual property rights? To what extent is bio-piracy by pharmaceutical companies possible?

Table 2. Ethnobotanical uses of plants in the U.S. (Hoareau & DaSilva, 1999; Dweck, 1997).

Scientific name	Popular name(s)	Uses	Medicinal properties/ chemicals
Eupatorium perfoliatum	Bonest	Used by American Indians as a laxative and tonic.	Contains volatile oil, tannic acid, and Eupatorin.
Podophyllum peltatum	Mayapple, Indian Apple, Umbrella Plant	Used for gastrointestinal disorders, rheumatism, and intestinal worms.	Podophyllin resin
Panax quinquefolium	Ginseng	Boosts the immune system, relieves stress.	Ginsenosides, protopanaxadiol, commercially available for relief of colds and flu.
Thuja occidentalis	Thuja; Cedarwood	Was used for treatment of psoriasis, rheumatism, and warts. American Indians made a tea of the bark to promote menstruation and to relieve headache.	Contains high concentration of vitamin C, and essential oil that is used as a disinfectant.
Echinacea angustifolia	American coneflower, Kansas snakeroot, Hedgehog.	To prevent inflammation (antiseptic) and to relieve pain (analgesic). The Omaha-Ponca used the root for toothaches and to treat snake bites. Builds the immune system.	In recent times, used to fight colds and flu. Echinacin extract has been found to have antifungal activity.
Sanguinaria canadensis	Indian Paint, Red Root, Sweet Slumber	Used to treat ringworm, fungal infections, ulcers, and skin diseases.	Alkaloids such as sanguinarine, protopine, cholerythrine; and chelidone acid.
Simmondsia chinensis	Jojoba	The Apache Indians used it for healing wounds.	Recent research has indicated that the oil is anti-inflammatory in its action.
Grindelia robusta	Gum Plant	California Indians used the plant to purify blood; today it is used for treating dermatitis.	Cerotic acid, phenolic substances, tannins.
Helianthus annuus	Sunflower	Sunflower oil used for psoriasis, relieves the pain of arthritis, and is used on bruises.	Triglycerides of linoleic acid (fatty acid needed for good skin condition).

These are but a few examples. Let your students do research on how indigenous plants are traditionally used in your state.

Formulating Hypotheses

Students are asked to formulate a hypothesis and make certain predictions. For example, students could hypothesize that *Sutherlandia frutescens* (or garlic, for that matter!) contains antimicrobial properties that could combat disease or improve the health of patients. We urge students to make predictions based on the hypotheses–e.g., a patient taking this muthi will enjoy better health, evident in an increased body weight (in the case of HIV/AIDS), and less frequent visits to healers/doctors. If you decide to use *Echinacea angustifolia* (see Table 2) as a plant, you will ask your students to hypothesize the health benefits of the plant. What prompted the Omaha-Ponca people to use the root of the plant for toothaches?

Collecting & Naming Plants

Many people use plants as a source of medicine for infectious diseases (microbial pathogens), using their own recipes passed down from generation to generation. Have students use a questionnaire to interview individuals who use plants in self-care to find out which plants are used, under what circumstances they are collected, and which methods are used to prepare the medicines. Before collecting the plant material, students need to obtain permission from the authorities, as indigenous plants may be protected and some species may be endangered.

Include garlic as one of the plants to be tested. If plant material cannot be collected from the field, use plants such as onion, orange and lemon rind, dried cloves, basil, gingko, yarrow, willow tree leaves (acetylsalicylic acid, aspirin), etc. An excursion to a herbarium can be planned to have the collected plant material identified. To save time, the teacher can have this done beforehand. Plan to collect plants the day before they are to be used. Store collected plant material in a cool place for use the next day.

Using an Experimental Design To Explore How Scientists Unravel the Secrets of Traditional Medicine

Experimental Design: Testing Anti-Microbial Activity of Plant Extracts

A very simple way of determining the susceptibility of a microorganism 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. The diameter of the zones can be measured with a ruler. The agar diffusion test provides a rapid assessment of antimicrobial activity for any water soluble compound. Here follows a step-by-step description of the laboratory procedures.

1. Preparing the Plant Material

- Wash the plant material (e.g., garlic, onion, orange or lemon rind, basil, etc.) with distilled water. (Tap water contains chlorine which may influence the experiment.)
- Coarsely shred the plant material in a sterilized mortar.
- Add distilled water and pound with a sterilized pestle until a paste forms.
- Add more distilled water to form a watery solution.
- Alternatively, you can use a blender to form a paste of the plant material.
- Pour into sterile test tubes.

2. Preparing Agar Plates for Testing the Antimicrobial Plant Substances

- We used the bacterium *Staphylococcus aureus* (Gram-positive coccus), but since it is a pathogen, we suggest you use the bacterium *Escherichia coli* or the fungus *Saccharomyces cerevisiae* (Baker's yeast) to test the effectiveness of an antimicrobial agent that may be present in the plant material. The *E. coli* strain called K-12 is very safe to handle; even if accidentally swallowed it will not result in health problems. Refer to the Web site http://www.microbiologyonline.org.uk/ecoli.htm.
- All materials that need to be sterilized can be placed in a pressure cooker, adding water to a depth of about 10 cm. Place the materials to be sterilized into glass petri dishes, or similar containers, on a rack that stands above the water level, and boil for about 15 minutes. Students can be divided into groups and each group tests two plants against the bacterium and the fungus.
- Use 15x100 mm petri dishes containing sterilized plate count agar (PCA). Alternatively, you can use a nutrient agar made by using a packet of tomato soup, to which enough gelatin is added to let it set in a solid form.
- The simplest method is to streak microbes onto the medium by using a sterile cotton swab to pick up and transfer the microbe to the PCA/tomato-gelatin medium plate. The plates should be cross-streaked/smeared in at least three different directions to cover most of the agar surface. This will result in even growth.
- Grow the bacterial cultures at 37 °C for 16-24 hours, and the yeast for 24-48 hours at room temperature (23-27 °C). The seeded plates should then be treated with the antimicrobial agent – see #1.

3. The Disk-Diffusion Method

- Use a forceps to aseptically select a sterile 6 mm diameter paper disk by its outer edge and dip into one of the prepared plant solutions (see #1). Remove excess solution by touching the disk to the inside rim of the test tube.
- Carefully place the disk on the micro-seeded agar plates. Don't reposition the disk or allow it to slide across the surface once contact is made.
- Treated plates are inverted and immediately placed in an incubator at 37 °C for 24 hours. After incubation, the diameter of the inhibition zone surrounding each disk is measured with a metric ruler. The measurement is taken from the center of the disk to the outer edge of the inhibition zone.
- A positive and negative control are needed:

  Negative control: Prepare a negative control in the same way as above, but use distilled water on a sterile disk.

  Positive control: Use a household disinfectant such as bleach (sodium hypochlorite) on a sterile disk as positive control.
- Each group of students tabulates their results. See Table 3 for an example.
- Students need to write a detailed report in which they present all data (results) and come to a conclusion.
- A follow-up experiment can be conducted to test minimum inhibitory concentrations. The results can be depicted as graphs.

Table 3. Results from the disk-diffusion assay showing antimicrobial activity of two plant extracts.

Name of Microbe	Plant 1	Plant 2	Negative control	Positive control
Bacterium, e.g., *Escherichia coli*	0	1+	-	3+
Fungus, e.g., *Saccharomyces cerevisiae*	2+	-	-	3+

Key: 0 indicates no inhibition; 1+ indicates 0.5-1 mm inhibition zone; 2+ indicates 1- 2 mm inhibition zone; 3+ indicates 2-3 mm inhibition zone

Chromatography Techniques

People critical of traditional medicine often refer to the fact that, although certain plants may have beneficial bio-active properties, identifying medicinal properties of muthi is complicated because different plants are often combined in making muthi and they are prepared in infusions and decoctions with little regard to standardized dosage. Also, whereas certain chemicals in the plant may have antimicrobial activity, other chemicals may be toxic. We therefore introduced a simple chromatography procedure in our course to demonstrate to the students how chemicals in plant materials can be separated.

- To prepare a leaf extract, put the plant material (spinach leaves work well) in a blender or cut it into small pieces using scissors, and grind them in a small volume of methyl alcohol.
- Put the plant extract in a test tube with methyl alcohol and place the test tube in a beaker with boiling water. The pigment dissolves in the organic solvent, which turns dark green (in the case of spinach leaves).
- Make a chromatogram (the visual output of the chromatograph) by following this process: Cut a long strip of filter paper. Draw a pencil line about 2 cm from the end. Using a thin capillary tube, plot a thin line of leaf extract (pigment) on

Table 4. Safety precautions.

Ether	Flammable solvent. Electrical apparatus must be removed from the bench and switched off. Use safety spectacles.
Acetone	Flammable solvent. Take precaution as above.
Microbial material	When using liquid cultures, use good techniques to avoid splashes. Never smell a microbial culture. Refer to: http://www.microbiologyonline.org.uk.

the pencil line. Allow it to dry, and then apply another layer.

- Place this developing chromatogram in a measuring cylinder in which a small amount of solvent has been added. The solvent should be 8% acetone and 92% ether. (Please refer to safety precautions in Table 4.) The meniscus of the solvent should not touch the pencil line.
- When the pigments have separated, remove the chromatogram from the measuring cylinder and allow it to dry.
- Let your students discuss how chromatography can be used to separate chemicals in medicinal plants.

What Are the Stages in Testing Medicines Before They Can Be Registered With the Medicines Control Council (FDA in the U.S.) as Treatments for Diseases?

The process needs to be explained to students.

- Pre-clinical studies involve in vitro (test tube or laboratory) tests and trials on animals (in vivo). The latter is a good topic for the de Bono activity discussed later in this article.
  - *Phase 0.* This is also known as human micro-dosing studies. A single sub-therapeutic dose of the drug is administered to a small number of people (10-15) to determine how the body processes the drug.
  - *Phase I.* A small group (20-80) of healthy volunteers is selected. The safety of the drug is tested. This phase is conducted in a clinic, where the volunteers are monitored by health workers. The subject who receives the drug is observed until several half-lives of the drug have passed. Phase I also includes dose-ranging, to find the appropriate dose.
- *Phase II.* Once the safety of the drug has been determined, Phase II trials are done on larger groups (20-300) to assess how well the drug works.
- *Phase III.* This involves randomized controlled multi-center trials on large groups (300-3000), and is aimed at a definite assessment of how effective a drug is. Only then can the drug receive approval from the FDA.
- *Phase IV.* This is a post-marketing surveillance trial. Harmful effects discovered in this phase may result in a drug being withdrawn from the market.

Using de Bono's Thinking Hats

After the above series of practical laboratory sessions, most students should be more appreciative of the role that traditional medicine can play in the national health system. We emphasize the fact that many traditional healers base their diagnosis on careful observations and methods also used in science. We also flag that modern science is providing growing evidence of good practice among traditional healers.

Edward de Bono developed a strategy that is very well aligned with our approach of infusing IK with Western science, and asking critical questions whether these epistemologies are in conflict or can co-exist. de Bono's thinking hats can be very helpful in assisting students to consider different viewpoints. All of us tend to think about matters in a particular way. Some people are emotional thinkers, and others more clinical. It is important that we sensitize learners that one can look at a particular topic from various perspectives. When dealing with controversial issues, de Bono's six thinking hats are very effective in making students sensitive to other points of view. Each of these hats describes a different thinking operation. Using the six hats forces one to consider the problem in several dimensions and from different perspectives, and is likely to encourage better thinking. Ask your students to view a particular problem/phenomenon (in this case, traditional medicine) by using each of the hats in turn. de Bono's hats can also be used to discuss the ethical issues surrounding the use of animals in the testing of drugs. Group work (small group discussions) will work well: Give each group a copy of the Six Hats Worksheet, as shown in Table 5. The six hats are:

- **White hat**. White is the color of paper, and the white hat is the "factual hat." This is a clinical or neutral colour and requires the thinker to discover the facts of the situation in an objective manner. It is the hat for data, detail, figures, information, and the asking of useful questions. (Make resources available to your students, or even better, let them do an Internet search.)
- **Yellow hat**. This is the bright and positive color. It requires the student to look at the good points in a situation or proposal. Why should this proposal work?
- **Red hat**. Red is the color of blood, and the red hat is the emotional hat. This is a hot color and encourages the

Table 5. de Bono's Thinking Hats: Example of students' responses.
Topic: Is there space for both Western medicine and traditional medicine in South Africa?

White hat (facts, questions) • 23,000 Western vs 300,000 traditional healers in South Africa • Traditional healing seems to be more holistic than western medicine. • Many black South Africans trust traditional healers, and not Western medical doctors. • Modern science is now providing evidence of good practice among traditional healers. • Studies on traditional use of plants during pregnancy have shown that, of 57 plants commonly used, 16 have been reported to be toxic (Ashforth, 2005).	**Red hat (feelings, intuitions)** • I believe that traditional medicine is based on superstition and meaningless pseudo mumbo jumbo that can be harmful to patients. • I feel that western science seems irrelevant to the everyday misery and suffering of poor, unemployed individuals and their families. • I am angry that traditional healing was declared illegal for a century under the Suppression of Witchcraft Act, by a racist Apartheid government.
Yellow hat (positive, why it will work) • The ANC's National Health Plan of 1994 will provide a good "marriage" between western and traditional medicine, and it honors peoples' right of access to whatever medical services they favor. • Research is showing that western and traditional medicine can complement one another. • The South African Traditional Medicines Research Unit of the Medical Research Council (MRC) has established a South African Traditional Medicines Research Unit so that traditional medicines can be researched.	**Black hat (caution, weak points)** • Too many traditional healers, and the products they use, are not registered according to the South African Medicines and Medical Devices Regulatory Act of 1998. • There are not sufficient "watchdog" measures in place to protect patients from unprofessional or unethical conduct by traditional healers.
Green hat (creative, alternatives) • Government should provide training to traditional healers to enhance the services they render to their patients. • Registration, according to the South African Medicines and Medical Devices Regulatory Act of 1998, should be better enforced, and structures to this effect should be put into place. • Western medicine should also look at the body and healing holistically.	**Blue hat (overview, holistic)** • Mutual education between the two health systems should take place so that all practitioners can be enriched in their health practices. • A guide for traditional healers titled *The South African Primary Health Care Handbook Combining Western and Traditional Practices* was produced. Stakeholders should be trained in this. (This was written in consultation with different traditional healer groups and is in line with the South African National Drug Policy, which emphasizes "the rational and safe use of medicines, including traditional medicines".)

student to allow his/her emotions, intuition, and general feelings to hold court without any need for justice or substantiation. The thinker uses his/her emotions to lead the thinking.

- **Black hat**. This is a serious color, which encourages the thinker to be cautious about an idea or the subject under review. It is possibly the most important hat in critical thinking and prevents one's emotions from dominating a situation. The thinker plays devil's advocate and asks questions which are likely to expose weaknesses in a proposal.
- **Green hat**. This is the color of new growth in plants, heralding new beginnings and creative ideas. It is the hat that invites lateral solutions, creativity, and innovative suggestions.
- **Blue hat**. This is the color of the sky and suggests an overview of one's thinking. It is the meta-cognitive hat. It challenges the thinker to be self-analytical, evaluative and to think holistically.

As an example, we shall look at the perceived friction that is evident between Western medicine and traditional medicine. Let students spend a few minutes on each of the hats during group discussions. Make provision for feedback from the groups.

Note: The teacher can do the de Bono hats activity before the lab investigations are done, but in our experience one tends to get too much of a red-hat focus then. After the laboratory investigations, students have a much more balanced view of traditional medicine.

○ de Bono's Hats & the SSI Approach

With a socio-scientific issues (SSI) approach, students are encouraged to consider how science-based issues affect their own lives, and to reflect on the moral principles that underpin science. The *National Science Education Standards* refer to the STS approach. SSI adds a moral dimension to this focus. It has already been mentioned that traditional healing practices were illegal in South Africa, and this was, of course, an infringement of human rights. Heated discussions about this took place in our classrooms, and de Bono's thinking hats seemed an effective tool in structuring the debate.

○ Findings & Conclusions

Students reflected very positively on the above approach. So inspired were some of the students that four of them applied for admission

Table 6. Useful resources for the American life science teacher.

Web sites	Books and journals
Encyclopedia Smithsonian: http://www.si.edu/Encyclopedia_SI/nmai/nafood.htm	*Western Medicinal Plants and Herbs.* Steven Foster & Christopher Hobbs. 2002.
Microbiology Online http://www.microbiologyonline.org.uk	*Medicinal Plants of the World.* Ivan Ross. 2003.
Green Medicine http://www.nps.gov/plants/MEDICINAL/plants.htm	*The Electronic Journal of Biotechnology.* www.ejbiotechnology.info

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the following year to the Botany Department of the local university to study ethnobotany. During focus group interviews with eight of the students, comments such as the following were made:

> *Wow, I never imagined that botany can be so interesting! I will give ethnobotany and phytomedicine serious consideration as a possible future career.*
>
> *This was the most exciting biology I have ever done! It made me proud to be an African scientist.*
>
> *I enjoyed the De Bono hats exercise. It was fun to look at the issue of western science VS traditional medicine from the different hats perspectives.*
>
> *I realized how central moral issues are in the way we practice science.*

Judging from the essays that students had to write on ethnobotany and their performance on a written examination, the above intervention was effective in giving students a more balanced view of such controversial issues. Just over 90% of the students articulated that the two health systems can complement one another. Many of the students referred to the advantage of a more holistic approach to health in traditional medicine, and the advantage of scientific intervention when there are systemic problems in Western medicine.

Our observations made us realize that such an SSI approach is also valuable in promoting affective outcomes in the classroom. During the focus group interviews, the majority of students indicated how much they enjoyed the series of lessons, and how it made science become alive.

In conclusion, Gough (2007) quotes St. Pierre (1997) who states "... we must learn to live in the middle of things, in the tension of conflict and confusion and possibility; and we must become adept at making do with the messiness of that condition." Moral issues have always been at the core of science. In the future, with advancements in molecular biology and genetics, the life sciences teacher will have to deal with such issues to an even greater degree. This might ask the life sciences teacher to, in Deleuzian language, move to a new "space." A space not imbedded exclusively in either Western science or indigenous knowledge systems, but the space shared between these two constructs. In this space, it will ask the teacher to put on his/her de Bono blue hat and look at complex issues in a holistic fashion.•

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