

Learning about Science & Pseudoscience as Critical Consumers: A Classroom Activity on the Rationality of Plant, Medicinal & Cosmetic Products Use

• Josef de Beer, Ben-Erik Van Wyk



Artemisia afra

ABSTRACT

In the 21st century, which is often characterized by fake news and pseudoscientific claims, it is important that students should engage with the tenets of science, and how it differs from pseudoscience. The Rationality Index for Plant Use (RIPU) tool, introduced in this article, could be used in a problem-based and cooperative learning activity, where students explore the tenets of respectively science and pseudoscience. During such a learning activity, students will engage with scientific literature to either find support for hypotheses, or to nullify it. The activity also holds affordances to sensitize students toward the processes of science and the realization that scientists publish their findings in high-quality, peer-reviewed journals.

Key Words: *tenets of science; pseudoscience; indigenous knowledge; hypotheses; scientific literature.*

○ Introduction: Science & Pseudoscience

It is essential that students become science-literate citizens and critical consumers. We are bombarded in the media with products and marketing campaigns that can best be described as pseudoscience. One can just think of the health and beauty industries, e.g., numerous products that claim to assist in weight loss, without much scientific evidence supporting such claims. Allgaier's (2019) research showed that a large percentage of videos on YouTube related to climate change "support worldviews that are opposing scientific consensus views." In December 2019 humankind was introduced to a new threat, in the form of the COVID-19 pandemic. Several studies that were initiated to find a vaccine for the virus were withdrawn, either because ethical guidelines were not followed or because of pseudoscience that resulted in discordant and distorted data (Kasapçopur, 2020). Very often poor science is camouflaged by the use of scientific terminology. It is important that students develop a nuanced understanding of the tenets of science—i.e., its empirical, tentative and inferential nature (Abd-El-Khalick et al., 1998)—and that science findings are communicated in high-quality, peer-reviewed journals. Students also have to distinguish

between science and pseudoscience, utilizing the tenets of science as a heuristic. Such skills would assist students in being critical consumers in the complex 21st century.

Pseudoscience can be defined as an imitation of science to "create the appearance of scientific activity while actually neglecting its fundamental principles" (Livshits, 2020, p. 212). Pavić (2013, p. 145) states that pseudoscience demonstrates "pretensions of scientific validity, argumentations, facts and theories resembling scientific ones ... but do not conform to the strict standards that scientific theories are expected to fulfill." The literature lists a number of characteristics of pseudoscience (Pavić, 2013):

- It often makes unfalsifiable and vague statements.
- It often ignores contradicting evidence and chooses only confirming empirical evidence.
- It shows a reliance on anecdotal evidence, and thus unreliable data is considered reliable.
- It displays positive evidence bias, only utilizing data that confirms its hypothesis, not looking for evidence that might falsify its hypothesis.
- It places the burden of proof on people who try to falsify the hypothesis.

○ What Distinguishes Science from Pseudoscience? What Could the Role of Indigenous Knowledge Be?

Indigenous knowledge provides a wonderful vehicle for learners to explore the tenets of both science and pseudoscience. Several articles on the infusion of indigenous knowledge in the biology curricula have been published in the *American Biology Teacher* (De Beer & Whitlock, 2009; De Beer & Van Wyk, 2011; De Beer, 2012; De Beer & Petersen, 2017a; De Beer & Petersen, 2017b), and in these articles the focus was on capitalizing on the shared tenets between science and indigenous knowledge systems. For example, both knowledge systems are empirical (nature is real, observable, and testable), tentative (the knowledge is subject to

change, based on new findings), and inferential (there is a distinction between observations and deductions/conclusions). Ethnobotany especially holds promise in the biology classroom, to promote higher-order cognitive and affective outcomes and more nuanced understanding of the nature of science. Pavić (2013) states that modern medicine is allopathic (based on scientific principles). Many modern medicines were developed from ethnobotanical (indigenous knowledge) roots. Van Wyk and colleagues (2000) draw attention to the fact that natural products and their derivatives are well represented in terms of all the drugs in clinical use in the world. A few well-known examples of plant-derived medicines include quinine, morphine, codeine, aspirin, atropine, and cocaine. In many parts of the world, people are still reliant on plants for medicines. Classroom activities related to ethnobotany could include testing the antimicrobial activity of medicinal plants, using the Kirby-Bauer technique (De Beer & Whitlock, 2009), or engaging in an ethnobotanical survey in the community (De Beer & Van Wyk, 2011). Such learning activities are aligned with the tenets of science and should develop an appreciation of indigenous knowledge in students.

However, an aspect that cannot be ignored, is that indigenous knowledge systems are holistic, with often a strong metaphysical component. Van Wyk and colleagues (2000, p. 10) state that “each culture has found solutions to the preventive, promotive and curative aspects of health that resonate in harmony with the world view of that culture.” One example is, for instance, the use of plant products for spiritual reasons. Bussmann (2016) claims that “magic” plants have been part of traditional medicine for millennia. An international example is the use of *Ruta graveolens* (rue) for divination in Italy, namely “against spirits, and for enchantment and as an antidote against deadly poisons and serpents” (Leonti et al., 2010, p. 389).

Such indigenous knowledge, encompassing both empirical science and metaphysical aspects, provides a good vehicle for engaging learners in the exploration of the characteristics of science, the limits of science (spirituality is a different domain), and how science and indigenous knowledge differ from pseudoscience. De Beer (2020) developed a Rationality Index for Plant Use (RIPU), a heuristic with a set of questions that would result in an overall statistical measure (index) of the rationality of a specific use of a plant (whether medicinal or magical use). This RIPU is limited to plant uses that have a biological and pharmacological basis. The tool does not make provision for symbolic and ritual uses of plants. One also needs to acknowledge the value of the placebo effect. In a study of 19 placebo-controlled trials, Barnes (2003) showed that homeopathic medicines were significantly more effective than placebos but that the placebo effect cannot be ignored. The RIPU tool requires students to engage with scientific literature. Ellis (1990) has shown that professional scientific journals could sensitize students to the rigor of scientific research and create awareness of the critical role of scientific literature in science. Engagement with this tool could assist students to (a) develop an understanding of the value of peer review in the natural sciences and of how not all publications are equal and credible; (b) engage with search engines other than Google (e.g., the Scopus citation database or SciFinder); (c) formulate hypotheses on plant use by cultural groups; (d) learn about the chemistry of medicinal plants (or pharmaceutical products); (e) engage with in-vitro and in-vivo experiments in literature for testing plant extracts (or active ingredients in medicines); and (f) make conclusions on whether there is sufficient evidence of effective use of a specific plant (or use of a commercial product).

○ The Questionnaire, RIPU, and Preliminary Research on the RIPU Tool

De Beer (2020) wanted to develop an index that is easy to use. The tool provides five questions, each with multiple possible answers.

1. Number of original anecdotes recorded on the plant and its use(s)
 - 1.1. How many original anecdotes have been published?
 - None = 0
 - One or two only = 1
 - Three to ten = 2
 - Eleven to twenty = 3
 - More than twenty-one = 4
 - 1.2. Were these anecdotes published in accredited, peer-reviewed publications?
 - No, it was published in grey / low impact journals = 1
 - Yes, it was published in respected peer-reviewed publications = 2
 - 1.3. How many unpublished anecdotes have been recorded?
 - One to ten = 1
 - Eleven to twenty = 2
 - More than twenty-one = 3
2. Is there a workable (plausible) hypothesis for the plant's use(s)?

No = 0.

 - It is possible to speculate on the merit of the plant use = 1
 - The hypothesis is unpublished (or published in grey literature) = 2
 - The hypothesis is published in low-impact journals = 3
 - The hypothesis is published in high-quality journals, but there are still unanswered questions = 4
 - The hypothesis is confirmed and published in high-quality journals = 5
3. Chemical evidence
 - The chemistry is unknown = 0
 - Little is known on its chemistry = 1
 - The chemistry is known, but irrelevant to its use = 1
 - The chemistry is known and is related to its use = 3
 - The chemistry is very well recorded and clearly linked to its specific use; there is no doubt on its effectiveness = 5
4. In-vitro evidence for the plant use (preclinical tests)
 - No in-vitro tests have been done = 0
 - Little or doubtful in-vitro testing was done = 1
 - Some in-vitro testing supports the specific plant use = 2
 - Extensive in-vitro testing has been done, with varied results, or results indicating limited effectiveness = 3
 - There is good evidence of rigorous in-vitro testing that supports the plant use = 5
5. In-vivo evidence for the plant use
 - No in-vivo testing has been done = 0
 - Some evidence of in-vivo testing in animals has been done = 1
 - Good evidence that in-vivo testing in animals has been done = 2

- Some evidence that in-vivo testing in humans has been done = 3
- Sufficient evidence that in-vivo testing in humans, with either mixed results or indicating limited effectiveness, has been done = 4
- Very good evidence that in-vivo testing in humans, indicating the efficacy of the plant use, has been done = 6.

A specific plant use could have a maximum score of 30, which, when divided by 30, would result in a Rationality Index of Plant Use of 1.0 (whereas a score of 27 out of the possible 30 would result in a RIPU value of 0.9), which would indicate that the plant use is rational. A score of 6 would result in a RIPU value of 0.2 (6 divided by 30), which would indicate that there is not much scientific data to support the rationality of such a plant use). Students can utilize search engines, such as Google Scholar, Scopus, or SciFinder, to guide their research into medicinal and/or spiritual plants in their environments, or to assess evidence for claims made about commercial health products. SciFinder is produced by the Chemical Abstracts Service, and it is the most comprehensive database for chemical literature.

At the North-West University in South Africa, research has begun on the use of the RIPU tool, within a problem-based and cooperative learning environment, to enhance student teachers' understanding of the tenets of science, indigenous knowledge, and pseudoscience. The findings will be disseminated in another publication. The authors have, however, engaged practicing science teachers in a learning activity on the RIPU during a workshop, and afterward conducted a focus group interview with six teachers. Coding of teachers' responses resulted in five provisional themes:

- Teachers indicated that the RIPU tool could enhance creativity, active involvement of students in science, and interest in scientific research and career opportunities.
- Teachers emphasized the complexity of the activity, and that it could foster self-directed learning, as students will have to set learning goals for themselves.
- Teachers valued the fact that the RIPU tool and cooperative learning activity could enhance respect for different cultural groups and their indigenous knowledge (which is of critical importance in a post-apartheid, democratic South Africa).
- All the teachers held the opinion that the activity will only be suited to higher grades, due to its complexity, and that the teacher will have to provide effective scaffolding of learning.
- Teachers expressed the concern that, in rural, underresourced classrooms in South Africa, challenges related to sufficient data availability and internet connectivity may hamper the successful implementation of such a learning activity.

This engagement with practicing teachers assisted us in providing guidelines to successfully utilize the RIPU tool in the classroom.

We suggest that students engage with plants that are locally used by indigenous knowledge holders. A medicinal plant that is widely used in the tropics and subtropics of the Americas is the resin of gumbalimba (*Bursera simaruba*), which is reported to be used as a tea to treat gout, backache, urinary tract infections, and fever (<https://www.permaculturenews.org/2016/02/05/6-magical-and-medicinal-trees-to-grow-in-the-tropics>). Noguera and colleagues (2004) have shown that the plant has anti-inflammatory

activity. Another example of a popular plant is noni (*Morinda citrifolia*), also known as the beach mulberry, which has been used to treat high blood pressure, arthritis, depression, inflammation and intestinal worms (<https://www.permaculturenews.org/2016/02/05/6-magical-and-medicinal-trees-to-grow-in-the-tropics>). Although it is an exotic plant in the Americas (it originated in Southeast Asia), it is also well-known in the tropical and subtropical parts of the continent. Chemical analysis revealed the existence of more than 200 phytochemical substances with bioactive properties, as well as antimicrobial and antioxidant properties (Almeida et al., 2019).

By engaging learners in such an activity utilizing the RIPU tool, a number of learning objectives can be achieved. This activity is well-aligned with the National Science Education Standards (National Research Council, 1996), which emphasizes the connections between traditional scientific disciplines (p. 115). This activity could enhance the achievement of the outcome stated, "As students develop and understand more science concepts and processes, their explanations should become more sophisticated ... frequently reflecting a rich scientific knowledge base; evidence of logic; higher levels of analysis; and greater tolerance of criticism and uncertainty" (p. 117). This activity would be best implemented in higher grades (9–12), and this content standard would be very applicable to the RIPU activity: "Students should develop the abilities associated with accurate and effective communication. These include reviewing information, summarizing data, and constructing a reasoned argument." The activity might also be suitable to AP Biology, with its strong focus on the chemistry of life and cellular energetics.

To illustrate the use value of the RIPU, the authors provide Table 1, an example of a literature review utilizing the RIPU for *Artemisia afra*, a medicinal plant widely used in South Africa (and elsewhere in the world), otherwise known as African wormwood.

The RIPU score is 1.0. The use of *Artemisia afra* for medicinal reasons is completely rational, based on plausible hypotheses that were tested in-vitro and in-vivo. Often, the use of the RIPU tool would result in a low index. For example, if the object of study is a commercial product that claims to assist in weight loss and there is not sufficient scientific data to support such a hypothesis, the validity of such a health claim should be questioned. Table 2 provides a short summary of the rationality of the use of *Galium tomentosum*, which is traditionally used in Khoisan communities in South Africa, to forget traumatic experiences. Due to page limitations, most of the technical and chemical details are excluded. The RIPU value of 0.33, however, shows that the use of the plant does not seem to have a rational basis and that more in-vitro and in-vivo research would be needed to support its traditional use.

○ How to Structure Such a Learning Activity

We suggest students work in small groups of four to promote cooperative learning. Such an activity should be structured according to the basic elements of cooperative learning, as described by Johnson and Johnson (2009), namely ensuring positive interdependence, individual accountability, face-to-face promotive interaction (which is defined by Johnson and Johnson as social interaction that promotes participation and contribution in group work among students while they are supporting, encouraging and praising each other's efforts to carry out their joint task), social skill development, and group processing (see also De Beer & Petersen, 2017b). Each group will first have to identify a problem to investigate. This could

Table 1. Determining the rationality index of plant use of *Artemisia afra*. (A simplified version appears in the unpublished thesis of De Beer, 2020, p. 102).

Item in the RIPU Questionnaire	Discussion: Measuring Plant Use against Criterium	Score
<p>1.1. How many original anecdotes have been published?</p> <ul style="list-style-type: none"> • None = 0 • One or two only = 1 • Three to ten = 2 • Eleven to twenty = 3 • More than twenty-one = 4 	<p><i>Artemisia afra</i> is one of the most widely used plant medicines in South Africa. Reported uses include treatment of coughs, colds, and influenza (Dykman, 1891; Watt & Breyer-Brandwijk, 1962; Van Wyk et al., 2000); bronchial troubles (Liu et al., 2009); fever, loss of appetite, colic, headache, earache, malaria, intestinal worms (Watt & Breyer-Brandwijk, 1962; Hutchings, 1989; Van Wyk et al., 2013), and diabetes (Nortje, 2011). Liu and colleagues (2009) show that it is often used in combination with other plants (e.g., <i>Lippia asperifolia</i>) to treat measles. Van Wyk & Wink (2015) refer to the use of poultices and nasal plugs to treat a blocked nose. Patil and colleagues (2011) report on its use to treat menstrual cramps and epilepsy.</p>	4
<p>1.2. Were these anecdotes published in accredited, peer-reviewed publications?</p> <ul style="list-style-type: none"> • No, it was published in grey / low impact journals = 1 • Yes, it was published in respected peer-reviewed publications = 2 <p>Adams and colleagues (2016) refer to publications in high-quality, peer-reviewed journals as “white literature.” In contrast, “grey literature” are not subjected to an academic peer review process.</p>	<p>The plant’s uses and chemistry are described in high-quality publications, for example Van Wyk and colleagues (2013), Van Wyk & Wink (2015), and in accredited journals such as the <i>South African Journal of Botany</i>, and <i>Journal of Infectious Disease Pharmacotherapy</i>.</p>	2
<p>1.3. How many unpublished anecdotes have been recorded?</p> <ul style="list-style-type: none"> • One to ten = 1 • Eleven to twenty = 2 • More than twenty-one = 3 	<p>In all probability, many have been recorded. De Beer and Van Wyk (2011), for example, recorded anecdotes during their 2009–2011 ethnobotanical survey of the Agter-Hantam in Middelpos, South Africa.</p>	3
<p>2. Is there a workable (plausible) hypothesis for the plant’s use(s)?</p> <ul style="list-style-type: none"> • No = 0 • It is possible to speculate on the merit of the plant use = 1 • The hypothesis is unpublished (or published in grey literature) = 2 • The hypothesis is published in low-impact journals = 3 • The hypothesis is published in high-quality journals, but there are still unanswered questions = 4 • Confirmed hypothesis, published in high-quality journals = 5 	<p>Since <i>A. afra</i> is rich in terpenes it is likely to have valuable biological activities (Liu et al., 2009). The hypothesis that the plant has a broad spectrum of inhibitory activity against pathogens has been confirmed by researchers such as Mangena and Muyima (1999). Martini and colleagues (2020) have tested the hypothesis that <i>A. afra</i> has strong bactericidal activity. Another hypothesis, namely that <i>A. afra</i> could reduce spontaneous rhythmic and agonist-induced contractions of the duodenum and ileum, and so ease stomach pains and intestinal cramps, has been tested by Mulatu and Mekonnen (2007). Naidoo and colleagues (2008) tested the hypothesis that, due to its antioxidant activity, it has anticoccidial potential and could therefore be effective in treating inflammatory diseases.</p>	5
<p>3. Chemical evidence</p> <ul style="list-style-type: none"> • The chemistry is unknown = 0 • Little is known on its chemistry = 1 • The chemistry is known, but irrelevant to its use = 1 • The chemistry is known, and is related to its use = 3 • The chemistry is very well recorded and clearly linked to its specific use; there is no doubt on its effectiveness = 5 	<p>The volatile oil contains, amongst others, 1,8-cineole, α-thujone, β-thujone, camphor, and borneol (Van Wyk et al., 2013). It also contains terpenoids, coumarins, and acetylenes (Van Wyk, 2008). Liu and colleagues (2009) provide a comprehensive list of all the monoterpenoids and sesquiterpenes, with author citations. The chemistry involved in its many uses has been studied comprehensively, namely its broad spectrum of inhibitory activity against pathogens, its spasmolytic properties, cardiovascular effect, antioxidant activity, and antidepressant activity (Liu et al., 2009).</p>	5

(Continue)

Table 1. (Continued)

Item in the RIPU Questionnaire	Discussion: Measuring Plant Use against Criterium	Score
<p>4. In-vitro evidence for the plant use (pre-clinical tests)</p> <ul style="list-style-type: none"> • No in-vitro tests have been done = 0 • Little or doubtful in-vitro testing was done = 1 • Some in-vitro testing supports the specific plant use = 2 • Extensive in-vitro testing has been done, with varied results, or results indicating limited effectiveness = 3 • There is good evidence of rigorous in-vitro testing that supports the plant use = 5 	<p>Extensive in-vitro work has been done. Mangena and Muyima (1999) tested extracts from <i>A. afra</i> against a wide range of microorganisms (including gram-positive bacteria, gram-negative bacteria, and fungi species). Other researchers who worked on the antimicrobial activity of <i>A. afra</i> against bacteria include Rabe and Van Staden (1997). These authors have showed that the plant exhibit strong bactericidal activity against <i>Mycobacterium tuberculosis</i>. Poswal and Witbooi (1997) have evaluated <i>A. afra</i> oils against <i>Pseudomonas syringae</i>. Regarding its use in combatting protozoan infections, Kraft and colleagues (2003) revealed that the lipophilic extracts of <i>A. afra</i> showed high activity against <i>Plasmodium falciparum</i> (causing malaria). In-vitro work has also been done by Gruessner and colleagues (2019) on the plant's ability to treat malaria. Joel and colleagues (2013) studied the pulmonary effects of <i>Artemisia afra</i> extracts in isolated perfused lungs.</p>	5
<p>5. In-vivo evidence for the plant use</p> <ul style="list-style-type: none"> • No in-vivo testing has been done = 0 • Some evidence of in-vivo testing in animals = 1 • Good evidence of in-vivo testing in animals = 2 • Some evidence of in-vivo testing in humans = 3 • Sufficient evidence of in-vivo testing in humans, with either mixed results, or indicating limited effectiveness = 4 • Very good evidence of in-vivo testing in humans, indicating the efficacy of the plant use = 6 	<p>Several in-vivo tests have been done on <i>A. afra</i> (Patil et al., 2011). Gathirwa et al. (2007) studied the efficacy of <i>A. afra</i> as an antiplasmodial substance in mice. Mice treated with methanolic extracts had a longer survival time compared to mice treated with a water extract. Kraft (2003) showed that flavonoids (7-methoxyacacetin, acacetin, genkwanin, and apigenin) and sesquiterpene lactones result in the antiplasmodial effect. Mulatu and Mekonnen (2007) did in-vivo work testing an ethanolic extract of <i>A. afra</i> leaves for its influence on the digestive tract, namely the mouse duodenum and guinea pig ileum. Munyangi and colleagues (2018) report on in-vivo work in a large clinical trial, including 800 patients, to test <i>A. afra</i>'s ability to treat schistosomiasis (bilharzia). The plant provided faster and more effective treatment (compared to the standard praziquantel treatment).</p>	6
Total score	A score of 30/30, thus, is the RIPU 1.0.	30

Table 2. Determining the Rationality Index of Plant Use of *Galium tomentosum*

Item in the RIPU questionnaire	Discussion: Measuring Plant Use against Criterium	Score
1.1. How many original anecdotes have been published?	A few medicinal uses have been recorded, for example the plant's use as an antidiabetic substance or as a general tonic. However, the focus here is only on its spiritual use. Nathen (2016), Nortje (2011), and Hulley & Van Wyk (2017) all report on its use as a medicine against witchcraft spells.	3
1.2. Were these anecdotes published in accredited, peer-reviewed publications?	Yes, these studies have been published as postgraduate dissertations and in accredited scientific journals.	2
1.3. How many unpublished anecdotes have been recorded?	In all probability, many unpublished anecdotes have been recorded.	2

(Continue)

Table 2. (Continued)

Item in the RIPU questionnaire	Discussion: Measuring Plant Use against Criterium	Score
2. Is there a workable (plausible) hypothesis for the plant's use(s)?	Little is known about the chemistry of <i>G. tomentosum</i> . Studies done in rats with <i>G. verum</i> extracts under anakinetic stress conditions have resulted in the enhancement of neurosecretory activity of the hypothalamic paraventricular nucleus, activation of adenohipophyseal hormones, and stimulation of the adrenal steroid hormones (Al-Snafi, 2018). One such hormone is cortisol, which combats the effects of stress. It could therefore be possible that the extracts of <i>Galium tomentosum</i> could reduce stress and create a feeling of well-being. Its common name, <i>rooivergeet</i> (which translates to "red-forget") might also alert to possible qualities related to memory loss (e.g., forgetting traumatic experiences). It is known that certain plant alkaloids, including scopolamine (hyoscine), can lead to memory loss and hold potential as antidepressants (Balmus & Ciobica, 2017). Further chemical analysis of <i>Galium tomentosum</i> 's alkaloids might show similar action on the acetylcholine system through muscarinic receptor blockage. Research is currently done on a drug, a histone deacetylase inhibitor, that interferes with one of the ways that brain cells record memories (Gräff et al., 2014).	1
3. Chemical evidence	The chemistry of <i>Galium tomentosum</i> needs attention.	1
4. In-vitro evidence for the plant use (preclinical tests)	In-vitro work has been done with extracts from species such as <i>Galium odoratum</i> and <i>Galium verum</i> , but not on <i>G. tomentosum</i> .	1
5. In-vivo evidence for the plant use	The endocrine effects of <i>Galium verum</i> extracts were tested in rats (to determine its effects as an anti-stress medicine), but studies have not been done on <i>G. tomentosum</i> . Hardly any in-vivo work has therefore been done of the plant's spiritual uses.	0
Total score	A score of 10/30, thus, is the RIPU 0.33	10

either be an indigenous plant use (e.g., a plant culturally used for medicinal or spiritual reasons), or it could be a commercial product that claims to have certain health or beauty benefits. Utilizing the RIPU tool, students will then, in small groups, engage with literature to find evidence to either support or nullify the hypotheses. A high RIPU value (0.7–1.0) show that such product/plant use has a rational basis. A low score (0–0.3) indicates that the use is highly implausible. The “grey” area (0.4–0.6) indicates that more research into the chemical working of the product is needed.

Ellis (1990) emphasizes that students might find it daunting to engage with professional scientific journals (a point also raised by the teachers who participated in our focus group interview), and she suggests that a teacher-led discussion should precede the actual activity. Provide a few exemplars of in-vitro and in-vivo clinical tests to the students and underline that not being familiar with the myriad of scientific (especially chemical) terminology is not a problem. Explain to the students that “white literature” (Adams et al., 2016) refers to high-quality journals that subscribe to rigorous peer review, and refer students to the peer-review policy of the selected journals. Students should be sensitized to the fact that if a journal does not subscribe to rigorous peer review, it might be seen as “grey literature.” Ellis (1990, p. 235) describes scientific literature as the “backbone of scientific research,” and such engagement with

scientific journals will provide the students a glimpse into the world of researchers. As the students engage with the RIPU task, they will identify many gaps in their knowledge. Sensitize them to the notion of self-directed learning. Knowles (1974, p. 18) describes self-directed learning as “a process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources, choosing and implementing appropriate learning strategies, and evaluating the outcomes”. A video diary might be an effective tool in supporting such self-directed learning.

What are the potential outcomes of engaging in an activity applying the RIPU to specific plant use or investigating medicinal or beauty claims of products?

- Science is not static, and with the growth in ethnobotany comes new evidence for the rationality of plant use, based on chemical, pathological, and pharmacological research. Students could, through their engagement with research literature, develop more nuanced understandings of how research findings could either support or nullify medicinal or health claims.
- Students will realize that scientists publish their research in peer-reviewed journals and that a distinction should be

made between scientific journals and popular publications. When a product claims to induce weight loss, a scientifically literate person should seek evidence for such a claim from clinical studies published in high-quality, peer-reviewed journals.

- The RIPU tool provides students with the opportunity to formulate hypotheses and look for possible evidence in literature that could support such hypotheses.
- Students will develop an understanding that in-vitro and in-vivo work need to be done to validate any medicinal claims of plant products.
- Based on the RIPU score, students will have to formulate conclusions on how rational a particular plant use (or claims made about a commercial product) is.
- The activity will engage students in exploring the tenets of science, indigenous knowledge, and pseudoscience.
- The activity will sensitize students toward new career options that exist, for example in bioprospecting, pharmacology, and microbiology.

○ Conclusion

Problem-based learning is a strategy in which students' learning processes are embedded in real-life problems (Hung et al., 2007), and the RIPU activity provides such an opportunity. As mentioned, the COVID-19 pandemic has center-staged the role of science in our daily lives and how one should be aware of pseudoscientific claims. After the groups complete their research, a lively class discussion could follow.

References

Abd-El-Khalick, F., Bell, R.L. & Lederman, N.G. (1998). The nature of science and instructional practice. *Science Education*, 82(4), 417–37.

Adams, R.J., Smart, P. & Huff, A.S. (2016). Shades of grey: Guidelines for working with grey literature in systematic reviews for management and organizational studies. *International Journal of Management Reviews*, 19(4). <https://doi.org/10.1111/ijmr.12102>.

Allgaier, J. (2019, July 25). Science and environmental communication on YouTube: strategically distorted communications in online videos on climate change and climate engineering. *Frontiers in Communication*, 4. <http://doi.org/10.3389/fcomm.2019.00036>.

Almeida, E.S., de Oliveira, D. & Hotza, D. (2019). Properties and applications of *Morinda citrifolia* (Noni): A review. *Comprehensive Reviews in Food Science and Food Safety*, 18(4), 883–909.

Al-Snafi, A.E. (2018). *Galium verum*: A review. *Indo American Journal of Pharmaceutical Sciences*, 5(4), 2142–49.

Balmus, I.-M. & Ciobica, A. (2017). Main plant extracts' active properties effective on scopolamine-induced memory loss. *American Journal of Alzheimer's Disease and Other Dementias*, 32(7), 418–28.

Barnes, J. (2003). Quality, efficacy and safety of complementary medicines: Fashions, facts and the future. *British Journal of Clinical Pharmacology*, 55(4), 331–40.

Bussmann, R.W. (2016). Magic plants. In U.P. Albuquerque & R. Alves (Eds.), *Introduction to Ethnobiology*. Springer International Publishing.

De Beer, J. (2012). Investigating the influence of karrikins on seed germination. *American Biology Teacher*, 74(5), 324–29.

De Beer, J. (2020). *An Ethnobotanical and Anthropological Study of the Medicinal and Magic Plants of Southern Bushmanland, Northern Cape, South Africa*. PhD thesis, unpublished, University of Johannesburg.

De Beer, J. & Petersen, N. (2017a). A laboratory investigation on the role of ethylene in seed germination from an indigenous knowledge perspective. *American Biology Teacher*, 79(1), 55–61.

De Beer, J. & Petersen, N. (2017b). Post-harvest physiology of cut flowers: A problem-based, cooperative learning activity for the biology classroom. *American Biology Teacher*, 79(7), 578–83.

De Beer, J. & Van Wyk, B.-E. (2011). Doing an ethnobotanical survey in the life sciences classroom. *American Biology Teacher*, 73(2), 90–97.

De Beer, J. & Whitlock, E. (2009). Indigenous knowledge in the life sciences classroom: Put on your De Bono hats. *American Biology Teacher*, 71(4), 209–16.

Dykman, E.J. (1891). *Kook-, koek en resepte boek*, Paarlse Drukkers Maatskappy, Paarl.

Ellis, L.K. (1990). Using scientific journals in the secondary science curriculum. *American Biology Teacher*, 52(4), 235–39.

Gathirwa, J.W., Rukunga, G.M., Njagi, E.N.M., Omar, S., Guatai, A.N., et al. (2007). In vitro anti-plasmodial and in vivo anti-malarial activity of some plants traditionally used for the treatment of malaria by the Meru community in Kenya. *Journal of Natural Medicines*, 61, 261–68.

Gräff, J., Joseph, N.F., Horn, M.E., Samiei, A., Meng, J., et al. (2014). Epigenic priming of memory updating during reconsolidation to attenuate fear memories. *Cell*, 156, 1–30. <https://doi.org/10.1016/j.cell.2013.12.020>.

Gruessner, B.M., Cornet-Vernet, L., Desrosiers, M.R., Lutgen, P., Towler, M.J. & Weathers, P.J. (2019). It is not just artemisinin: *Artemisia sp.* for treating diseases including malaria and schistosomiasis. *Phytochemistry Reviews*, 18(6), 1509–27.

Hulley, I.M. & Van Wyk, B.-E. (2019). Quantitative medical ethnobotany of Kannaland (western Little Karoo, South Africa): Non-homogeneity amongst villages. *South African Journal of Botany*, 122, 225–65.

Hung, D. & Chen, D.V. (2007). Context-process authenticity in learning: Implications for identity enculturation and boundary crossing. *Education Tech Research Dev*, 55, 147–67.

Hutchings, A. (1989). A survey and analysis of traditional medicinal plants as used by the Zulu, Xhosa and Sotho. *Bothalia*, 19(1), 111–23.

Joel, M.S., Abraham, S.J. & Chibuzo, O.K. (2013). Pulmonary effects and disposition of luteolin and *Artemisia afra* extracts in isolated perfused lungs. *Journal of Ethnopharmacology*, 149(3), 648–55.

Johnson, R.T. & Johnson, D.W. (1999). Making cooperative learning work. *Theory into Practice*, 38(2), 67–73.

Kasapçopur, O. (2020). Science and pseudoscience during the COVID-19 pandemic. *Turkish Archives of Pediatrics*, 55(4), 335–36.

Knowles, M. (1975). *Self-directed learning: A guide for learners and teachers*. Follett.

Kraft, C., Jenett-Siems, K., Siems, K., Jakupovic, J., Mavi, S., et al. (2003). In vitro antiplasmodial evaluation of medicinal plants from Zimbabwe. *Phytotherapy Research*, 17, 123–28.

Leonti, M., Cabras, S., Weckerle, C., Solinas, M.N. & Casu, L. (2010). The causal dependence of present plant knowledge on herbals: Contemporary medicinal plant use in Campania (Italy) compared to Matthioli (1568). *Journal of Ethnopharmacology*, 130, 379–91.

Liu, N.Q., Van der Kooy, F. & Verpoorte, R. (2009). *Artemisia afra*: A potential flagship for African medicinal plants?. *South African Journal of Botany*, 75(2), 185–95.

Livshits, R. (2020). The markers of pseudoscience. *Advances in Economics, Business and Management Research*, 128, 212–21.

Mangena, T. & Muyima, N.Y.O. (1999). Comparative evaluation of the antibacterial activities of essential oils of *Artemisia afra*, *Pteronia incana* and

- Rosmarinus officinalis* on selected bacteria and yeast strains. *Letters in Applied Microbiology*, 28, 291–96.
- Martini, M.C., Zhang, T., Williams, J.T., Abramovitch, R.B., Weathers, P.J. & Shell, S.S. (2020). *Artemisia annua* and *Artemisia afra* extracts exhibit strong bactericidal activity against *Mycobacterium tuberculosis*. *Journal of Ethnopharmacology*, 262, 113191.
- Mulatu, A. & Mekonnen, Y. (2007). Spasmolytic effects of *Artemisia afra* and *Artemisia rehan* in tissue preparations. *Ethiopian Medical Journal*, 45, 371–76.
- Naidoo, V., McGaw, L.J., Bisschop, S.P.R., Duncan, N. & Eloff, J.N. (2008). The value of plant extracts with antioxidant activity in attenuating coccidiosis in broiler chickens. *Veterinary Parasitology*, 153, 214–19.
- Nathen, T. (2016). *Exploring 'assemblages': A multi species ethnography of the relationship between plants and people in the gardens and mountains of Klawer in the Matzikama municipal region*. Master's dissertation, University of the Western Cape.
- National Research Council. (1996). *National Science Education Standards*. National Academy Press. <http://www.nap.edu/catalog/4962.html>.
- Noguera, B., Diaz, E., Garcia, M.V. & Feliciano, A.S. (2004). Anti-inflammatory activity of leaf extract and fractions of *Bursera simaruba* (L.) Sarg (Burseraceae). *Journal of Ethnopharmacology*, 92(1), 129–33.
- Nortje, J.M. (2011). *Medicinal Ethnobotany of the Kamiesberg, Namaqualand, Northern Cape Province, South Africa*. Master's dissertation, University of Johannesburg.
- Patil, G.V., Dass, S.K. & Chandra, R. (2011). *Artemisia afra* and modern diseases. *Journal of Pharmacogenomics and Pharmacoproteomics*, 2(3), 1–22.
- Pavić, Z. (2013). Science and pseudoscience in postmodern societies. *Informatologia*, 46(2), 145–53.
- Poswal, M.A.T. & Witbooi, W. (1997). Antibacterial properties of essential oils on *Pseudomonas syringae* pv. *syringae* and *Pseudomonas solanacearum*. *Developments in Plant Pathology*, 9, 606–10.
- Rabe, T. & Van Staden, J. (1997). Antibacterial activity of South African plants used for medicinal purposes. *Journal of Ethnopharmacology*, 56, 81–87.
- Van Wyk, B.-E. (2008). A review of Khoi-San and Cape Dutch medical ethnobotany. *Journal of Ethnopharmacology*, 119, 331–41.
- Van Wyk, B.-E., Van Oudtshoorn, B. & Gericke, N. (2000). *Medicinal Plants of South Africa*, 2nd ed. Briza.
- Van Wyk, B.-E. & Wink, M. (2015). *Phytomedicines, Herbal Drugs and Plant Poisons*. Kew and Briza.
- Watt, J.M. & Breyer-Brandwijk, M.G. (1962). *The Medical and Poisonous Plants of Southern and Eastern Africa*. Livingston.

JOSEF DE BEER (jdebeer@uwc.ac.za) is the director of the Science Learning Centre for Africa, Faculty of Education, University of the Western Cape, Cape Town, South Africa. BEN-ERIK VAN WYK is a taxonomist and holds a research chair in indigenous plant use, in the Department of Botany and Plant Biotechnology, University of Johannesburg, South Africa.

TheDNAStore.com
DNA Products for the classroom