Environmental science practices integrated with IK: The case of soot

[1]Muzwa Mukwambo, [2]Kenneth M. Ngcoza and [3]Charles Chikunda
[1]UNAM (Katima Mulilo Campus) and [2,3]Rhodes University, Grahamstown, South Africa
[1]mmukwambo@unam.na, [2]k.ngcoza@ru.ac.za and [3]cchikunda2@gmail.com

Abstract
The integration of IK in science practices, in which various cultural practices, artefacts and science language reflecting western science indigenous communities (IC) use, is sometimes not well-explained to learners. Consequently science teachers grapple to incorporate IK with science concepts in the curriculum. In this study, global warming due to soot ranking second only to carbon dioxide is investigated, to see how ideas IC use can be incorporated into environmental science classrooms.

Activities in which IC interact with soot are there in the community but not documented. For instance, indigenous communities discourage one another to fetch water from a water source using a soot-contaminated container. To understand more of this cultural practice in order to successfully incorporate knowledge advanced and used; this study used brain storming, practical work, interviews and reflections to generate data. Activities IC engage in were incorporated as case studies and practical activities in in Grade 11 science practices, first by teachers and then by learners. In doing so, a culturally responsive pedagogical style emerged.

Investigation emerged ideas indigenous communities use and how their incorporation into environmental science/teaching practices were achieved and possibly assisted in reducing global warming. Findings were IC cultural practices related to soot can be incorporated in teaching concepts of global warming and also, such approach brings about culturally responsive pedagogical styles.

Keywords: *soot, truth theories, global warming, practices, indigenous communities*

Background

Studies done on global warming suggest soot as a major contributor and point how it can be curbed (Gronewold, 2009; Jacobson, 2002; Wijaya, 2014). The studies that were conducted in the developed countries argued that under-developed countries were the major contributors to global warming. Jacobson (2002) posits that global warming due to soot ranks second only to carbon dioxide. Developing countries are said to contribute more in global warming as if in all their activities they engage with do not take cognizance of the effect of practices which might endanger the environment through soot. In support is Bond and Roden (2006) in a study conducted in Honduras where they posit that developing countries are at the forefront in producing soot as 2 billion people in developing countries use wood stoves that emit soot particles.

It might be that developing countries contribute more to global warming as more wood stoves are found in these areas since that is the only alternative source of heat energy. Gronewold (2009) supports the idea that developing countries are major contributors of global warming as he suggests that vast swaths of the world population rely on wood or charcoal as principal sources of energy. Even though such a scenario exists, some communities in developing countries are aware of the adverse effects of soot coming from wood stoves. However, they cannot act to stop engaging cultural practices which emit soot, they are economically weak to opt for other sources of energy generation friendly to the environment (Wijaya, 2014), but if they reason logically about other cultural practices friendly to the environment and relate them they should win bringing about a clean environment**.** This is evidenced from certain cultural activities which they practice. For instance, in some indigenous communities (ICs) located in Southern African Development Community (SADC) Zimbabwe, South Africa Botswana and even in Namibia, where this phenomenon was observed, some ICs discourage one another from using soot contaminated utensils to fetch water from pools or any other source(s) of water. Even though science teachers are aware of this practice some still grapple to incorporate this IC practice in their science teaching. In a study Mukwambo (2016) conducted in the Zambezi Region of

Namibia, revealed that the IC understood that the soot dust darkens the substrate and fosters increased heating and evaporation in water bodies.

Accepting that soot absorbs more heat as the Pacific Northwest National Laboratories (PNNL) (2011) suggests that this causes ice to melt faster. This scenario deprives those farmers of water to irrigate their crops since they depend on melted ice to irrigate crops. Ramanathan and Carmichael (2008), Pravetton (2009), and Chen (2012) have also revealed how soot contributes to global warming.

Indigenous communities, however, have been aware of these effects for some time since other communities discourage community members to use soot contaminated utensil. This is a cultural and historical practice in many SADC countries. Such knowledge has been and is still used, in particular, by indigenous communities to curb the effects of global warming. Mukwambo and Ngcoza (2015) suggest that indigenous communities use cultural practices based on understanding of how soot contaminates water bodies and how it can be avoided in order to reduce excess evaporation of water, as well as preventing the accumulation of large amounts of energy from the sun. Western modern science (WMS) refers to this phenomenon as the Albedo Effect (Akbari, Matthews & Seto, 2012). The Albedo Effect forms one of the cultural practices that this study investigated for use in science teaching. The objective of the study focused on how IC practices related to soot can be used in science practices. Also, when learners know the benefits of the Albedo Effect as practiced by IC, this will raise the level at which community members keep practising this and as a result reduce global warming since it will be practiced at a larger scale. Furthermore, it aimed at finding how the Albedo Effect, based on the views of IC can be brought into science practice through the use of practical activity which Conole (2008) advocates as one of the mediating artefact useful in mediating learning.

Sometimes, when science teachers engage in practical work as mediating artefacts, the activities learners engage in are not those found in the learners' environment. The activities are disconnected from the learners' experience (Duschl, Schweingruber, & Shouse, 2007). The practical work activities selected are those reflecting WMS resulting in failure of learners to understand what the activity imparts to them since they do not reflect the learners' culturally science related situations. Culturally, according to Aikenhead (1997) when science-related situations are selected as the starting point when teaching science are understood to allow science learners to understand the concepts advanced in the activity.

Since the culturally science related situations approach to teaching science allow science teachers to probe learners' prior knowledge, this allowed this study to investigate IC practices to be engaged in practical activities as teachers explored how ideas indigenous communities used could be incorporated into teaching concepts in environmental science and possibly assist in reducing global warming. An example where indigenous knowledge indigenous community possess save a community is that (Elias, Rungmanee, and Cruz, 2005) report on coping strategies applied with mixed success to guide themselves against the Indian Ocean tsunami which struck in 2004 among the Moken and UrokLawai peoples of Thailand's coasts. For this reason, we found indigenous knowledge as useful and has some science which can be incorporated into WS taught in school to minimize the gap where some teachers grapple to incorporate IK. For example, in this study, to incorporate IC practices on global warming attributed to soot, IC practices related to how IC understood the effect of soot on global warming focused on the cultural practices IC engaged in.

Indigenous knowledge

Even though indigenous knowledge (IK) and prior everyday knowledge are indicated as more or less the same, IK is more specific. IK comes into a community as the community members intend to use it to better their welfare just as western science. After community members have scrutinized their prior knowledge and experiences, they will then convert it into IK. Kibirige and Van Rooyen (2006) consider IK as "a legacy of knowledge and skills unique to a particular indigenous culture and involving wisdom that has been developed and passed on over generations" (p. 2).

Since the focus of this study is on how indigenous knowledge related to how communities protect the environment to prevent global warming, we view IK as

cultural knowledge that a given community widely adopts and is used as a source of knowledge to sustain a community. Cultural practices explored in this study are a component of indigenous knowledge that indigenous communities use. The emphasis of IK falls on different issues from community to community, sometimes with a greater focus on the conservation of ecology (which is referred to as Traditional Ecological Knowledge or TEK (Kibirige & Van Rooyen, 2006). Depending on how indigenous knowledge is used, this might bring another focus of what IK is. For instance, those who view that IK is silenced by WS can define IK as an epistemological therapy device (Mukwambo, Ngcoza, & Chikunda, 2019).

To support the argument that IC practices reflect science and are true and can be used to minimize a problem where some science teachers grapple to incorporate IK into WS, the truth theories were used. These were used as conceptual framework to support the data that emerged.

Theories of truth as conceptual framework

Consensus on what truth is has not yet been reached, but, however, certain theories exist which can be used to say what is true. In order to support the findings which emerged in the study of how cultural practices were used as the focus of a practical work in order to show how IK views can be incorporated in WS, the correspondence, pragmatic and coherence theories were used. Bealle (2000) and Tape (2009) view the correspondence theory as speculating that knowledge, cultural practice or a belief is true if there exist facts corresponding to reality. Verification is achievable through observation and physical measurements in the correspondence theory. Coherence theory according to Schmitt (2004) posits that certain cultural practices may have no connection with reality, but are internally consistent (coherent) between statements in a closed system. There is a need in this theory to ensure that cultural practices and the cultural artefacts which are the products of the activity fit in with other accepted beliefs. On the other hand the pragmatic theory from the view of Hammond and Stewart (2001) posits that a belief, cultural practice or a product of cultural activity (cultural artefact) is true if it works for whatever purpose you need it. That is cultural practices that ICs engage in help to reduce or prevent the effects of global warming.

Significance of the study

There is much to learn from IK, cultural artefacts and cultural practices -based approaches to global warming prevention. Indigenous communities are confronted with changing environments for years, for instance, the 2004 tsunami among the Moken and UrokLawai peoples of Thailand's coasts as mentioned before. ICs have developed a wide array of coping cultural practice strategies, and their traditional knowledge and practices deliver an important basis for facing the even greater challenges of climate variation. Although their strategies may not be successfully and completely done, they are effective to some degree and that is why the people continue to use them. So when these are brought into a classroom they might be reinforced or the community members see the need to keep on using them. In doing so, the learner applies knowledge gained into practical use.

Limitation of the study

Although the cultural practices under investigation adhere to the truth theories mentioned above, that is they manifest coherence and correspondence with knowledge in WS and are applied to curb global warming, science teachers might still harbour negative feelings about their use. This makes it impossible to apply them in science teaching and learning as an alternative. This brings some limitation to their use even though they might be a solution as seen through practical activities in the methodology section used in this study to verify them. To mitigate the situation where science teachers harbour negative feelings and grapple to use cultural practice reflecting science, we came with research questions.

The research questions to achieve the mentioned objective were as follows:

1. How can science teachers in the Zambezi Region incorporate indigenous practices related to global warming in science practices?
2. How can science teachers incorporate IC practices related to soot in science practical work practices?

Methodology

This qualitative study consisted of two phases: the first phase centred on the researchers and the six participating science teachers brainstorming cultural practices in which ICs take cognizance of the effect of soot on the environment Also, representatives of ICs participated when they came to explain to the science teachers their beliefs about soot practices. This led the science teachers to look the IK concepts related to soot were looked for in the practices of indigenous communities. These were investigated to find out how they corresponded, cohered with concepts in WS and also whether the cultural practices helped the community to prevent global warming. Verification using practical work based on ICs' practices with soot followed.

The second phase entailed assigning the six willing participating teachers to conduct the practical work related to cultural practices in soot and present it among themselves and thereafter to their science learners so that the learners understood what global warming was. Thereafter interviews were conducted with science teachers and finally, the teachers were assigned to do reflections. The data generated from the activities of the teachers and learners were practical in nature. Instead of experimenting on phenomena reflecting global warming outside the learners' environment, the teachers decided to conduct a practical activity in which a cultural practice seen in learners' communities which act as accessible prior knowledge. Also, the tasking of the six science teachers to conduct a practical work aimed at ensuring that reliability is addressed. Each teacher was asked to average the value of each variable measured and record. These values obtained by each teacher were then compared for sameness and finally concluded if there was consistent results time after time.

Data presentation

The activities which the teachers conducted with their learners incorporated the use of two recycled 2 litre plastic soft drink containers shown in Figure 1. Equal amounts of water were poured into the containers labelled as A and B. In container A, a teaspoonful of soot obtained from a container normally used for warming water over an open wood fire was scratched from underneath and poured into it. In both containers a thermometer was inserted to measure the temperature changes. The two were then placed in an open space. This was aimed at verifying whether the soot the IC believed enters into water when a soot contaminated container is used to fetch water has an effect on increasing the temperature which then according to WS increases the internal energy of water particles and evaporates faster.

Another set of apparatus was aimed at verifying the ICs observation which they had stated during a visit with the science teachers that water contaminated with soot becomes less in quantity compared with one which is soot free as stated in the methodology section.

A B

Figure 1: Application of the Albedo Effect in Indigenous community cultural practices

In Figure 1, container B acted as the control. The one litre of water poured in each of the two containers A and B came from the same source. This was aimed at ensuring that if impurities existed in the water, the rate of evaporation would not be interfered with if A

did not have soot in it. The set of apparatus was placed at the same place so that the factors which affect evaporation were the same for the four containers.

The factors affecting evaporation of water are wind, heat, surface area of water in the container, nature of liquid, humidity and vapour pressure. When science teachers were verifying the science concepts in the practices of ICs and when they presented to the learners, the containers were placed at the same spot allowed them to absorb the same amount of heat energy, receive the same amount of air and experience the same amount of humidity and pressure. The use of the same type of recycled 2 litre plastic soft drink containers ensured that the surface area was a constant and finally using water from the same source guaranteed that the nature of the liquid used was the same.

The thermometers inserted in each container measured the temperature. The recordings of temperature change in containers A and B (Figure 1) were done for recycled 2 litre plastic soft drink containers hourly. The continuous data generated from A and B is presented in Table 1.

Table 1: Temperature and time variation of a sample of water with soot in Beaker A and without soot in Beaker B (control)

Time (Hrs.)	Beaker A (temperature ^{o}C)	Beaker B (temperature ^{o}C) [control]
08:00	24	24
09:00	36	31
10:00	37	35
11:00	40	37
12:00	41	40
13:00	42	40
14:00	40	36
15:00	38	33
16:00	35	31
17:00	31	27
18:00	28	25
19:00	27	23
20:00	26	19

The recordings in Table 1 facilitated the construction of a graph of temperature and time (see Figure 2).

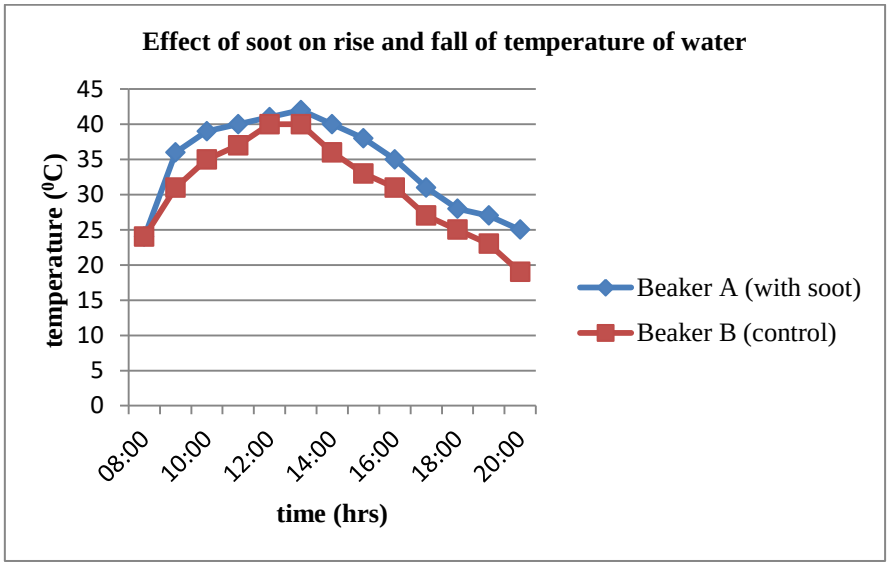

Figure 2: Graphical presentation of effect of soot on temperature changes

Figure 3: Volumetric presentation of amount of water remaining in A and B after

The information from the graph became useful to check whether the data generated supported the correspondence, coherence and pragmatic truth theories discussed in the previous section. Also, data generated from measuring the volume of water left in A and B (Figure 3 was analysed together with data generated from interviews and reflections.

Data analysis from interviews and reflections

The science teachers were tasked to answer four questions which were posed during the interviews. The interview questions like the practical work were aimed at giving response to the research questions highlighted before. Can IC practices related to soot be incorporated in science practices? Can IC practices related to global warming concepts attributed to soot incorporated with WS using practical work? How can science teachers incorporate IC practices related to soot in science practical work practices?

In the interview the teachers were asked whether use of case studies or practical work related to soot and global warming could be used as a way to incorporate IK with WS. The science teachers responded that from the experience they gained from the activity, a case study could be used to explain to the learners what was taking place. In doing so, the teacher or learner who explains, is in a position to describe the phenomena of global warming using concepts from both knowledge systems. The practical work acted as a way to consolidate concepts which were discussed.

In relation to whether IC practices related to global warming concepts attributed to soot could be incorporated with WS using practical work, the practicing teachers pointed out that it had a benefit. The benefit mentioned became that of contextualizing the teaching of global warming. Furthermore, they went on to say to respond that use of IC practices related to global warming from learners' culture perpetuates the use of the practice. In doing so they said will allow the young generation to desist from engaging in activities which might be responsible for global warming through producing soot. Examples given by the teachers included discouraging learners from burning forests, preventing burning of garden refuse at home and instead making a composite where the organic material decomposes naturally. Their arguments were further supported by what they pointed out in the reflections which showed learning through and from experience.

For instance, a theme which kept reoccurring in the reflections indicated that there was a need to have an IK café where cultural practices and artefacts would be showcased. This will help teachers in knowing case studies related to WS concepts they teach and how to contextualize them as practical activities for learners. Some of the teachers in their reflections pointed out that the cause of failure to understand global warming concepts could be attributed to examples of case studies and practical activities related to global warming which focus only on activities done in other foreign cultures. Activities related to curbing global warming in their community allows learners to understand and apply what they are taught and in so doing reduces activities associated with global warming. The data generated from other instruments is analysed below.

Analysis of data from brainstorming and practical work done

Data generated from brainstorming with the six science teachers reveals that there were some correspondence between concepts advanced in WS and those in IK related to global warming. Cultural practices where an IC understands effect to cause water sources to evaporate faster when soot contaminated, is a belief which corresponds to concepts in global warming as viewed from the lens of WS. For example each of the knowledge systems considers soot as an absorbent of heat energy from the sun. Soot contaminated water ends up at a higher temperature than soot free water as seen in Figure 2 and 3. The curve for soot contaminated water remained at a higher temperature than water in the control B. This evidence is also seen in Figure 3, where the amount of water in B is more than the amount of water in A. Considering the colours illustrated in the curves, we can say the blue curve shows the behaviour of soot contaminated water when it absorbs heat and time changes, it is at a higher temperature than the red curve. It lags behind during cooling and rises faster before it reaches the maximum value of 40^{o}C. On the other hand, the red curve shows the behaviour of water not contaminated with soot when it absorbs heat and time changes it lags behind, attains a lower value of 39^{o}C at its peak and cools faster.

A similar trend is also observed when volumes in container A and B were examined. Container "A" contaminated with soot had less water. However, in container "B" with soot free water, more water remained in it after the same period. This coheres with the concepts of global warming reflecting WS. WS posits that a black body absorbs more heat. Absorbed heat raises the internal energy of particles and as this happens they escape from the surface ending up as vapour. This raises the vapour pressure thus breaking the equilibrium which had existed before. Before, the two pressure systems were in equilibrium, the atmospheric and the vapour pressure were all contributing the same number of particles but the disequilibrium brought more particles escaping from the soot contaminated water.

Comments from the teachers as they were interviewed and other information coming from their reflections of IC practices are practical activities. Science teachers viewed IC practices as tools that could be used to prevent global warming due to soot which IC use to reduce global warming. In their view the IC practices when used in science teaching will prove useful in instilling an attitude of responsibility in the young generation currently studying science.

Discussions

From the teachers' views, IC practices related to soot can be incorporated in science practices as evidenced from what the teachers said in the interviews and reflections.

The IK concepts related to global warming when soot is under consideration correspond, cohere and help prevent excessive water loses in communities. It also helps to prevent heat to be retained on the earth surface as water bodies releases the heat absorbed during the day normally. A global warming activity from the view of IC practices is an example of where indigenous communities are applying their traditional knowledge about the environment to sustain it.

On whether IC practices related to global warming concepts attributed to soot can be incorporated into WS using practical work, the teachers agreed that explanation of science ideas in IK needed to be explained using a case study, thereafter; a practical activity can be conducted. According to our view this allows removing the disconnection which normally exists when practices from other cultures are used and this supports the view by (Duschl, Schweingruber, & Shouse, 2007). This enabled the participants to come up with the conclusion, which was drawn from the practical activity, which allowed the participants to consolidate the concepts taught. The fact that the science teachers mentioned that engaging a practical work which focus on IC activities allows a teacher to come up with a culturally responsive pedagogical style is evidence, supporting the use of practical work to teach environmental science concepts on global warming.

On how can the use of IC practices related to soot be used to reduce global warming? Science teachers suggested that the incorporation prevents young generation from shunning the practices as has been happening. The young generations who are the learners see how IC practices contribute in preventing global warming so this urges them to perpetually practice them and even avoid other activities contributing soot in the atmosphere.

Science teachers also pointed out that activities which they engaged in can also be very suitable for starting teaching the Green House Effect. Their opinion of the Green House Effect in most cases is discussed as attributed to carbon dioxide without talking too much on how soot perpetuates global warming.

The activities engaged in are culturally related situations which Aikenhead (1997) advocates as suitable for teaching science concepts. Also, the use of cultural practices related to the Albedo Effect as viewed from the lens of IC, served as a mediating artefact (Conole, 2008).

The correspondence, coherence and practical applicability of the cultural practices involving soot echoes with the truth theories put forward. Observations and hands-on practical activities the teachers carried out verified the reality surrounding cultural practices as Bealle (2000) and Tape (2009) propose. The congruency manifested between cultural practices and WS is what Schmitt (2004) believes should exist. The congruency lies in that the views IC have, echoes with Ramanathan and Carmichael (2008), Pravetton (2009), and Chen (2012) of the effects of soot. Finally, the observation that water with soot remained at a higher temperature is in support of the idea that IC take advantage of this to sustain the environment. This comes as a way of showing the usefulness of cultural practices explored and this is supportive of Hammond and Stewart (2001) view about truth in a particular activity.

Conclusion

Incorporating indigenous community practices when one knows whether the concepts observed correspond, cohere with WS can be achieved through use of a case study, thereafter, conducting a practical activity based on the same activities which the community engage in. The fact that the IC practices offer a solution to global warming threat is evidence enough that there is science which science teachers need to incorporate through a practical activity to consolidate concepts discussed in a class.

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