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Inclusion through Multicultural Science Education

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Abstract:
This paper is about the importance of inclusion of the diverse cultures of students in science lessons. In this paper, inclusion refers to the practice of addressing and responding to the diverse cultures of all learners through the incorporation of culturally valued knowledge and skills and culturally mediated instruction in science lessons with the objective of increasing student participation in learning and reducing exclusion within these lessons. The voices and experiences of all students must be heard and included in the school science curriculum. The paper contends that unless a deliberate effort is made to tolerate, acknowledge, appreciate and accept cultural diversity, those whose cultures are left out or ignored will feel excluded from the learning process. The paper advocates for science lessons in which unity in cultural diversity flourishes. In that scenario, school science content and instructional strategies used would incorporate the contributions of many cultures to the knowledge of school science. We believe that when schools value the contributions and uniqueness of children from all cultural backgrounds, the students will be able to see and appreciate the relevance of school science to their everyday lives and take a deeper interest in the science subjects. Education must be designed to perpetuate and enrich the culture of a people. We think that education cannot progress smoothly unless it is based upon and proceeds from the cultural perspectives of the group of people for whom it is designed. The paper suggests practical strategies of how this could be done, the role of the teacher, the challenges that are likely to be met and possible solutions to these challenges.

Keywords: *Inclusion, multicultural science education, culture, cultural diversity, culturally responsive/relevant teaching/pedagogy*

1. Introduction

The first thing we were told, when we went to do secondary school education, by those who were one year ahead of uswas: “There is a subject here called science. It is a very difficult one.” We wondered and asked ourselves: *What does this subject called ‘signs’ deal with which makes it so difficult?* We had not come across the word ‘science’ before. We knew ‘signs’. (At primary school we had been taught Nature Study.) We began to have a lot of anxiety. During our first few days in the science laboratories we were shown many funny looking objects and many funny smelling substances. We were told the funny looking objects were called apparatus and the funny smelling substances were called chemicals. ‘Apparatus. apparatus, chemicals, chemicals’ we kept repeating. Although these words were written on the chalkboard, and although we slowly and meticulously copied them into our note books, they were strange, completely unfamiliar, and completely meaningless to us. To remember all this, we had to memorise them. In other subjects the concepts were not that strange. For example, in Geography we learnt about continents, countries, mountains, rivers and valleys. All these words and these concepts were familiar to us. Not the words and the concepts in science!

Today’s learners of science may not have the same problems we had when we went to do secondary education as they now do ‘science’ at primary school level. This paper argues that even these current learners have problems related to unfamiliarity with school science concepts such as *fractional distillation of liquid air* and terminology which are completely alien to them. Imagine being told that the chemical symbol of tin is Sn and that of sodium is Na. Such concepts and terminology bewilder them and cause as much anxiety as they did to us in the mid- sixties. To survive, they must memorise what they are taught, just as we did or else they quit science learning. They become excluded. Exclusion could be physical, when the students quit science learning. (This could be one of the reasons why enrolment in science subjects is very low at Advanced and at tertiary levels in Zimbabwe, for instance). The exclusion could be conceptual where the students remain in the science class but fail to comprehend much of what is going on in the lesson as demonstrated by their lack of meaningful participation.

We also have an additional challenge where pupils' explanations of phenomena, which they learnt during their cultural socialisation differs from or contradicts the school science explanations for the same phenomena. Such pupils have their everyday life explanations as well as the school science explanations of, say, *the nature of lightning*. As Ogunleye (2009, p. 57) rightly puts it:

The current move toward 'science for all' in all parts of the globe necessitates that consideration be given to how pupils move between their everyday life and the world of school science, how pupils deal with cognitive conflicts between these two worlds, and what this means for effective teaching of science.

Ogunleye goes on to say that the clashes between pupils' lives and the world of school science can create problems for many pupils which they must deal with if they are to learn science effectively and meaningfully. Unless these conceptual differences are resolved, the students could experience cognitive dissonance. This means that where their prior knowledge is different from or contradictory to what they learn in school science, cognitive dissonance, amongst the learners, occurs as the learners start asking questions such as: *Which of these two explanations is correct?* Such confusion would impede their learning of school science concepts and make both science teaching and learning an ordeal for both teachers and pupils. Eventually, such students become excluded from science learning.

Where the learners' prior knowledge and skills are ignored during science lessons, the learners may wonder why their out of school experiences are not made part of the school science curriculum even where it would make good sense to do so. This makes the students to wonder the relevance of their home experiences or of the school experiences. Either way, the pupils are in a dilemma from which they should be rescued and brought out of, otherwise they become excluded.

Basing on the authors' experiences and on the reviewed literature, this paper argues that these learner problems and dilemmas can be ameliorated if culturally responsive teaching is employed.

1.1. Meaning of Inclusion through Multicultural Science Education

Inclusion through multicultural science education refers to the practice of addressing and responding to the diverse cultures of all learners through the incorporation of culturally valued knowledge and skills and culturally mediated instruction in science lessons with the objective of increasing student participation in learning and reducing exclusion within these lessons. Exclusion would mean a situation where students from some cultural groups would feel left out in science lessons through a deliberate effort by the school to undermine, side line, ridicule, or even demonise the culturally valued knowledge and skills and culturally mediated instruction which the students bring into the science lessons. Inclusion through multicultural science education is an extension of multicultural education which is defined by Banks (1995) as an educational reform movement and philosophy designed such that students from diverse cultural groups will experience equal educational opportunities in schools, colleges, and universities.

1.2. Historical Context of Inclusion in Multicultural Science Education

School science, which is the science taught in schools, is a subset of Western science which is a subset of Western culture. The history of Western science shows, among other revelations, that it is a very recent creation of a very few influential people such as the British Association for the Advancement of Science (BAAS) founded in 1831 and the Vienna Circle of 1922. These few, powerful and influential people decided what constitutes science and what does not. Their definition of science proved very exclusive and restricted. For example, some knowledge systems such as the indigenous knowledge systems (IKS), did not qualify to be called science since 'their knowledge could not be experienced empirically'.

The word science comes from the Latin word *scientia* which means knowledge. Defined in this inclusive way, it is not difficult to appreciate that science is not synonymous with the West. For example, many ancient civilisations, including those of indigenous peoples all over the world, collected enormous quantities of knowledge about their natural world in a systematic manner through careful observations over many years and could use that knowledge for many purposes related to their survival in the world they lived in including predicting weather patterns for both agricultural purposes and for taking necessary measures to avoid catastrophes such as floods, droughts, storms etc. The word scientist was coined very recently, in the 19th century, by William Whewell. Previously, people investigating nature called themselves natural philosophers.

In short, the bottom line is: School science is based on a culture that is alien to the majority of students in our schools. This means that school science is alien to these pupils.

1.3. The School Science and Students' Prior Knowledge Interface: The Myth

As noted above, school science is based on Western science. The students' prior knowledge is based on their cultural socialisation. Explanations of a phenomenon given by school science may differ or even contradict that given by the students' cultural socialisation. When this happens, we have cognitive conflict or dissonance as the student begins to wonder which explanation is correct. It may be a myth to think that school science will replace prior knowledge. Many scholars are of the opinion that efforts to replace indigenous worldviews with Western worldviews, over the many years of colonial rule, have not been successful. For example, Ogunniyi (1988) maintains that it is futile to try to replace indigenous knowledge with Western science because the learners will always have the indigenous knowledge with them at heart and in their minds. In his book, *The wretched of the earth,* Frantz Fanon (1967, p. 17) puts the same idea succinctly when he writes: "they can't choose; they must have both. Two worlds: they dance all night (to appease their ancestors) but fill the church in the morning to receive mass (from the local Christian priest). (In brackets, my own addition).

A way to prevent or at least lessen the cognitive dissonance should be found.

1.4. Theoretical Frameworks

A number of theories have been put forward by scholars to explain how students from different cultures move from their everyday lives into the world of school science and vice versa and how they are able to deal with the cognitive conflicts arising from the two worlds. Ogunleye (2009) contends that most of these theories emanate from the worldview theory.

Allen and Crawley (1998, p.113) define a worldview as:

---the way people think about themselves, their environments, and abstract ideas such as truth, beauty, causality, time and space. It is the way people have of looking at reality, the basic assumptions and images that provide a more or less coherent way of thinking about the world, the cognitive structure into which an individual fits new information.

The World View Theory believes that every person has presuppositions about what the world is really like and on what constitutes valid and important knowledge about the world (Cobern, 1993 in Pabale, 2005). These presuppositions are the views that a person holds about natural phenomena. Worldviews which the students bring with them into the science classroom may affect not only how they make sense of science information, but also the extent to which they are willing to participate in the educational experiences. Care must be taken to ensure that indigenous learners do not feel like outsiders or guests in the school science classroom. The assumption is that, an education system that ignores or refuses to recognise the learners' presuppositions, the learners' worldview, is likely to be unsuccessful.

The following are some of the theories which support the importance of prior knowledge where prior knowledge is defined as: All the experiences that the learners got through their cultural socialisation process (knowledge, skills, values, beliefs etc. that they learn in their communities).

1.4.1. Constructivism

Learning is the result of the interaction between the learner and the information that the learner encounters (Pabale, 2005). This interaction can be at individual or social/group level. The construction of new knowledge is strongly influenced by prior knowledge (Barnes, 1992; Berk & Winsler, 1995; Ausubel et al. 1978 in Naidoo, 2005). Meaning is constructed as the learners interpret the new information through the lens of prior knowledge. Learning of new knowledge is made easier when the new information is based on or related to prior knowledge.

1.4.2. Cultural Discontinuity Hypothesis (Kanu, 2007)

Prior cultural socialization influences how students learn in the school system, in particular how they negotiate, mediate, and respond to the school curriculum. Teachers need to take into cognizance these cultural socialisation processes. This includes how the students learn.

1.5. The Meaning of Culturally Sensitive or Responsive Science Teaching

A culturally sensitive or responsive science curriculum is one which emphasises culturally valued knowledge and skills and uses culturally mediated instruction. Culturally valued knowledge and skills refer to the knowledge and skills the learners have gained through their cultural socialisation and which they find relevant to their lives. Culturally mediated instruction would refer to ways of knowing, understanding, representing and interpreting information within a given culture. All these ideas embrace what is known as multicultural science education which Ladson-Billings (1995) refers to as culturally relevant pedagogy while Gay (2010), Hollins and Oliver (1999) refer to it as culturally responsive teaching. Gay (2010, p. 31) defines culturally responsive teaching as "using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant to and effective for them." Multicultural science education therefore means a shift in curriculum where new and diverse materials and perspectives from traditionally underprivileged groups are included in science lessons and where the diverse cultures can exist peacefully as members of the class begin to appreciate their own and other people's cultures. Multicultural science education recognises that science is found in all cultures (Luft, 1998). Kawagley et al. (1998) add their own view on this issue when they argue that no single origin of science exists and that science has a plurality of origins and a plurality of practices. The authors state further that after all Western science, on which school science is based, is not strictly Western in origin but a blend of the observations and insights of many cultures, notably, Egyptian, Greek, and Arabic.

For this paper, culture shall be taken to refer to the cumulative deposit of knowledge and skills, the totality of learned and accumulated experiences, meanings and how these are derived, and concepts of the universe acquired and possessed by a group of people which learners bring in the science lessons. It is important to note and emphasize that this basket of knowledge would differ from one cultural group of people to the other. Cultural practices shape thinking processes which serve as tools for learning within and outside the school (Hollins & Oliver, 1996). Culturally responsive education recognises, respects and uses learners' identities and backgrounds as meaningful sources for creating optimal learning environments (Nieto, 1999). Learners' prior experiences should form the basis of new learning. Science teachers must incorporate examples of indigenous science into their lessons and also teach children to respect the accomplishments of other cultures (Ogunleye, 2009).

1.6. The Importance of Culturally Responsive Science Teaching

The above paragraphs point to the fact that culture is central to student learning.Culture plays a pivotal role not only in communicating and receiving information, but also in shaping the thinking process of groups and individuals. A pedagogy that acknowledges, responds to, and celebrates fundamental cultures offers full, equitable access to education for students from all cultures. If cultural referents are used in science lessons, teachers would make the learning of science achievable and fascinating (Ladson-Billings, 1994).

According to Tobin(1991), learning in science is regarded as an interpretive process of making sense of new experiences in terms of extant (existing, living) knowledge. The heart of the learning process is the negotiation of meaning. Learners must be given opportunities to make sense of what is learned by comparing and linking what is known (what the students already know) to new experiences (what is being taught in the school), and resolving any discrepancies between what is known and the new experiences.

Learning is a result of learners making sense of the world they live in. Learners need to connect their school science learning to their out of school living (Gay, 2015)A problem arises when a learner's basis for making sense (extant knowledge, worldview and prior cultural experiences of the learner) is different from or contrary to how others in the class, including the teacher, make sense. One of the authors of this paper once witnessed a lesson on sources of safe/clean water. Alearner was laughed at by both the class and the teacher when the learner gave the example of *the river bed (mufuku)*as a source of safe water. It did not dawn on the teacher and his class that many people have used river beds as sources of water all their lives, generation after generation. In that same lesson a learner was praised for suggesting *water tap*as a source of safe water. It did not cross on the minds of the teacher and his class that a water tap is not a source of water, neither did it strike on them that it all depends on where the water is coming from: For example, is it from a borehole or a dam? This would determine whether the water could be considered safe on unsafe. The point is: Those learners, whose contributions are rejected when their contributions make a lot of sense, at least to them, are being excluded from the learning process because one would not want to volunteer to answer future questions when one's previous correct answers were ridiculed.

Not only does culturally science lessons promote inclusion, making use of learners' cultural knowledge in science lessons helps them to acquire more accurate knowledge about themselves and their lives, and appreciate their culture's contributions to academia (Gay, 2015).Gay (2010) also asserts that teaching learner's science through their own cultural filters, results in students' improved academic achievement.

Kober (1994) contends that effective science programmes should incorporate course content and activities that are relevant to the daily lives and out-of-school experiences of the learners. The implication of this is that learners need to work in a classroom environment which enables and encourages them to use their cultural tools such as language, preferred learning styles, prior learning, cultural myths and metaphors to make meaning of the science the teacher is trying to put across to them Once this has been done, once the science teachers understand and use the culture of their learners, they can and must stretch the students beyond the familiar. Science education must be designed to perpetuate and enrich the culture of a people.

1.7. The Role of Science Teachers in Culturally Sensitive Classes

Science teachers play a pivotal role in ensuring or facilitating inclusion through multicultural science education. They must find ways to help all their learners feel comfortable with and connected to science. As Barton (2000)observes, very often, the way science is represented and taught in the classroom tends to alienate many learners from science.Our mission as science teachers is to find effective ways to help learners construct their own understandings by incorporating their ideas into a fabric of concepts, skills and attitudes that carries meaning for them both academically and personally (Martin, Sexton, Franklin& Gerlovich, 2008). Teachers need to be aware of and knowledgeable about the diversity within their classrooms and facilitate the learning of all learners, many with cultural backgrounds that differ from the school science culture. We need to always remember that school science, which is a subset of Western culture, is alien to the majority of the science learners in our schools. Teachers need to recognize and respond to learner diversity and encourage all learners to fully participate in science learning (National Research Council, 1996). Teachers must accept and respect cultural pluralism in their science classes and view those differences as assets since they enrich their lessons. Culturally responsive teachers use the social-cultural capital and funds of knowledge of their science learners as resources for improving the educational achievement of the learners. Such teachers realise and make use of the fact that there is power, potential, creativity, imagination, ingenuity, resourcefulness, accomplishment, and resilience among their science learners (Gay, 2010). In addition, and in order to develop a community of science learners, teachers must display and demand, of their students, respect for the diverse ideas, skills and experiences of all learners (National Research Council, 1996).

As noted above, Kober (1994) argues that effective science programmes should incorporate course content and activities that are relevant to the daily lives and out-of-school experiences of learners. However, many science teachers have limited knowledge about the culture and history of their learners (Atwater, 1994). To maximise learning opportunities, teachers must gain knowledge of the cultures represented in their classrooms and translate that knowledge into instructional practice. Learners whose knowledge, skills and experiences are tapped by the school have an advantage in the learning process as their learning is accelerated while those whose prior experiences are devalued or unrecognised by the school, become alienated and disengaged from the learning process. They become excluded. If the school science curriculum is to be inclusive of all learners, it must be culturally sensitive and responsive.

In order to maximise the opportunities for all learners in science classrooms, teachers must be alert to biases in their science curriculum materials (Atwater, 1993) and make an effort to minimise the negative impact of such biases.

1.8. Challenges to Inclusion through Multicultural Education

It would be unrealistic to give the impression that culturally responsive science teaching is easy. For example, and as Gay (2015) observes, there is a lot of opposition to culturally responsive teaching. Gay contends that most of this resistance hinges on uncertainty about its validity or outright rejection of its reality and value in science education; anxiety about anticipated difficulties with its implementation; erroneously equating culturally responsive teaching with cheapening or diluting science education, and claiming incompetence (i.e. "I would do it if I knew how") without making any commitment to develop the needed knowledge and skills.

As noted earlier on, teachers may have limited knowledge about the culture and history of their learners (Atwater, 1994).Teachers may not be clear about what multicultural science teaching and learning look like in practice (Barton, 2000).

To the above challenges, we could add science syllabuses and examination boards which do not seem aware of or value the role of culture in learning and understanding science concepts. As a result, there is little, if any, reference to culturally relevant examples and questions. We also have resistance to embrace change in general. Teachers feel intimidated by change as change is associated with risks such as making mistakes, discovering in competencies due to lack of the required skills, and not succeeding (Taba, 1962).

1.9. Practical Suggestions on How to Teach Science for Inclusion

We will now use a few examples to show how teachers can and should use culturally responsive teaching in order to make science concepts accessible, interesting and relevant to the learners.

<u>1.9.1. Incorporating Cultural Course Content into the School Science Curriculum</u>

Below are a few examples of school science content areas which could benefit from incorporating cultural content.

<u>1.9.1.1. Separating Mixtures</u>

School science teaches the separation of many different substances through a variety of methods such as the use of magnets, filtration, evaporation, distillation, and fractional distillation**.** The substances used to illustrate these methods, such as sulphur and iron filings, are often taken from the science laboratory, except of course liquid air which nobody, including the teacher, has ever seen. The many different mixtures separated daily in the learners' home environments are not referred to. Our argument here is that the separation of maize seeds from nuts by hand when eating a mixture of the two; the separation of grain from chaff through winnowing; the use of sieves to separate chaff from beer, cow dung from milk; the separation of salt from soil to get salt from the earth using filtration and evaporation; the brewing of *kachasu* and *tototo* (highly intoxicating liquor) through distillation should form part of the school science curriculum. This way, learners would link home and school and find relevance in what they learn in science lessons.

<u>1.9.1.2. Chemical Reactions</u>

As we grew up, we knew that we could relieve a heartburn (accumulation of acids in the alimentary canal) by taking in ashes of fire from certain trees. In the science lessons, we never linked this common everyday experience toacid-base reactions to form neutral solutions through the *neutralisation of acids by bases.* Indeed, culturally sensitive teaching would have gone further to discover the identity of the base in the ashes.

If we wanted fresh milk to curdle quickly as we herded cattle in the forests, we mixed it with the juice from some sour fruits we collected there in the forest. There is something in the fruit juice that reacts with something in the milk to produce the curdled milk. Responsive science teaching would have made an effort to refer to these experiences and to identify these substances.

<u>1.9.1.3. Reactivity Series of Metals and Factors that Influence Rate of Chemical Reactions</u>

In science lessons, learners are taught that the rate at which different substances react is different. Some substances react faster than others. Learners have experienced that different trees differ at the rate they make fire. This could be a starting point to teach reactivity series and to identify the elements making up the different tree trunks.

Learners are told in their science lessons that the larger the surface area of solid reactants, the faster the rate of reaction. Learners know from their experience that it is easier to make fire using thin sticks or grass than using logs and that it is easier to cook mincemeat than to cook large chunks of meat. These two could be correlated in a culturally responsive science lesson.

With the above examples, the point we want to make here is: If these and other relevant examples are brought into science lessons, learners will be able to relate school science to their lives and school science becomes relevant. Can you imagine how remote and meaningless it is for a teacher in a remote rural area in Zimbabwe area teaching about *Fractional distillation of liquid air?* The students have problems in visualising liquid air and worse still, distilling it and the teacher cannot help much since he/she too does not have any relevant experience of the phenomenon at all. This is not to say that fractional distillation of liquid air and such alien concepts, should not be taught in science lessons, because, as we have argued above science lessons must be based on the cultural perspectives of the learners as well as on an extension of that cultural heritage of the leaners.

1.9.2. Using Cultural Methods of Teaching in Science Lessons

Have you ever wondered why people remember a lot of what happened and was said during their early socialisation years but forget what they were taught in school only yesterday? The answer lies, at least partly, in the way the two teachings were done. Culturally, people are taught in ways that are difficult to forget. School science teaching could benefit if it borrowed from cultural pedagogical methods. For example, using legends, myths or folktales that describe or explains a natural phenomenon is one such way of cultural teaching. Culturally responsive teaching would make use of this method of teaching and then compare the myth or legend with how scientists describe or explain the same phenomenon.

Here are a few examples to culturally explain the nature of lightning and thunder.

- Culturally, lightning is a hen that lays its eggs in one place. The hen then comes back either to lay more eggs or to check its eggs. In school science they are taught that certain places are prone to lightning i.e. some places are struck by lightning again and again. These two ideas can easily be linked. It would be unfair and unreasonable to ask: *Have you ever seen those eggs?* because it can also be asked: *Have you ever seen those electric charges?*
- In school science learners are taught that light travels faster than sound. (Light travels at $3 \times 10^8 ms^{-1}$ compared to the speed of sound which is $340ms^{-1}$). In our folk tales we are told that lightning is an energetic, ill tempered, destructive, quarrelsome young man while thunder is the young man's mother. Both were banished from the earth because of the unacceptable and destructive behaviour of the son. They now live in the skies. The young man is still very angry. Now and again he visits the earth to cause havoc perhaps as a revenge for his banishment. Whenever he comes down, his mother comes after him shouting to restrain him but he is fast and she is old and slow. She never catches him. When she arrives, he will have destroyed property and people. What an interesting way to teach: Lightning is very destructive and dangerous and that light travels faster than sound.
- Lightning takes on the form a bird called the lightning bird or *chimunga*. It is a large bird with a long-curled beak which it can use to cause serious wounds on its victims. We all know that people struck by lightning have wounds on their bodies. This folk tale could be used as the introduction to a science lesson on effects of lightning.

Such tales are more important for their motivational and captivating value rather than for their factual accuracy.

2. Conclusion

This paper, agreeing with Gallard (2016), has argued that the wide assortment of languages, customs and experiences associated with today's classrooms requires that teachers must take cognisance of these variations amongst their learners. In addition, because school science is a subset of the Western culture, learners from indigenous groups of people, who form the bulk of the science students in Zimbabwean schools, find that school science alien and often different from what they already know. To avoid cognitive dissonance amongst such learners and to ensure that such learners are not excluded physically or from meaningful participation in science lessons, teachers are being called upon to create classroom environments in which all learners can learn through the embracement of culturally sensitive and responsive science curricula.

Since most challenges related to inclusion through multicultural science education centre on the teacher, we recommend that teacher education programmes must include multicultural science education courses where the prospective teachers are taught how to handle multicultural classes of science and where the teachers' cultural understandings and worldviews of different societies are expanded. And as Gay (2010) suggests, it is necessary to restructure teacher attitudes and beliefs about the role of cultural heritage in science education because teachers' instructional behaviours are strongly influenced by their attitudes and beliefs about the role of culture in science education.

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