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INTERACTION OF INDIGENOUS AFRICAN CULTURE WITH SCIENCE: THE AGIKUYU CULTURAL KNOWLEDGE CONCERNING KINETIC THEORY OF MATTER

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Abstract

Science as a culture has been conceived as different from the culture of ordinary people especially in Africa. An orientation to indigenous culture has often been viewed to have an inverse relationship with the nature of science. Many of students' alternative conceptions about natural phenomena have been attributed to their cultural beliefs. Therefore, the trend in science education in African schools has been to alienate the learners' cultural knowledge and depict Western science as the only real description and explanation of reality. Yet, a relevant curriculum must be one that is adapted to the learner's context and that addresses the issues and challenges of the local society. The first step towards development of such curriculum should be to identify and examine how aspects of indigenous knowledge interact with the accepted science before they are integrated into the curriculum. This paper investigates the Agikuyu cultural knowledge concerning kinetic theory of matter. In particular, the paper examines how students of the Kikuyu ethnic community living in Nyandarua County interpret various situations with respect to their conceptions about heat. Results show existence of a particular metaphor concerning heat. The metaphor indicates an existing indigenous knowledge that interacts in a manner consistent with the accepted scientific view of kinetic theory of matter. From the results, it is concluded that there are scientifically rich cultural contexts within the indigenous knowledge of African societies. The paper recommends that there is need for education policy makers and curriculum developers to integrate aspects of indigenous knowledge that are consistent with the accepted science into the curricular of teaching science in schools.

Key Words: *African culture; Indigenous knowledge; Science; Metaphor; Kinetic theory*

Introduction

Science is considered as a second culture to the average African child (Zietsman & Naidoo, 2007). For this reason, an orientation to the indigenous culture is often viewed to have in inverse relationship with the nature of Western science normally taught in schools. According to Lynch (2005), most students' misconceptions of physical phenomena are attributed to their cultural beliefs. Research in developing countries has identified cultural influences on students' alternative frameworks in science concepts (Hewson & Hamlyn, 2004; Zietsman & Clement, 2006).

The trend in science education in African schools has been to alienate learners' cultural knowledge (Lackoff, 2000). This is despite the fact that children form conceptions about physical phenomena early in life as they try to make sense of the world they live in (Pfundt & Duit, 2004). The implication of this is that children have to cope with two sometimes conflicting knowledge about physical phenomena. This scenario leads to formations of alternative frameworks or misconceptions. The persistence of preconceptions of the physical world by children is attested to by the great deal of research that shows that children come to the science classrooms with a variety of ideas that are at variance with the accepted science (Caramazza, McCloskey & Green, 2011; Champagne, Klopper & Anderson, 2002; Clement, 2008; Osborne & Wittrock, 2003). The highly robust nature of these preconceptions indicate that they are deeply rooted in children's cognitive structures and makes plausible the idea that

they are grounded upon alternative frameworks (Lynch, 2005). Halloun and Hestenes (2007) observed that in most cases these misconceptions persist even after formal instruction.

Even though many students' preconceptions of the physical world are at variance and therefore detrimental to learning the accepted science, there could be areas where this knowledge is in harmony with the scientific theory. One such area could be the topic of heat. The topic of heat forms an important part of every science curriculum from primary school up to university level in the Kenyan education system. This topic is potentially interesting from the point of view of children's cognitive development stemming from the fact that children come into contact with 'hot' and 'cold' which are implicit sensation phenomena early in their life (Bar & Galili, 2004). This establishes contact between the child and his/her environment thereby providing greater individual experience.

Review of literature revealed considerable problems related to teaching and learning of heat concepts in the Western world (Harris, 2001; Se-Yuen Mak & Young, 2000; Van, Sprang & Verdonk, 2004). According to Harris, the term 'heat' is frequently misused by laypersons and scientists alike. The source of this confusion centers on the semantic use of words like 'heat flow', 'heat gained', 'heat capacity' and others. Hewson and Hamlyn (2004) observed a newspaper advertisement for an evaporative air conditioner in which it was claimed that as the water droplets evaporate; they consume the 'heat molecules' in the atmosphere thereby producing a cooling effect. The message of this advertisement is that 'heat' is matter consisting of molecules. This view of 'heat' is termed 'caloric' and is prevalent in the Western countries (Erickson, 2009). The view is inconsistent with the contemporary kinetic theory which explains physical phenomena associated with heat and which is taught in schools.

Researchers in the Western countries have found extensive caloric conceptions of heat in children, for example, in England, Shayer and Wylam (2001) reported that about 80% of their subjects used caloric conceptions to explain observable physical phenomena associated with heat. Such extensive caloric conceptions have not been reported in non-Western countries. On the contrary, Hewson and Hamlyn (2004) observed very few caloric conceptions among the Sotho people of Southern Africa. Hammond-Tooke (2001) documented a prevalent metaphor concerning heat among the Sotho people which was to a large extent in harmony with the accepted kinetic theory of heat. This study sought to establish whether there exists knowledge about heat among the students of Kikuyu ethnic community and how such knowledge interacts with the accepted science.

Objective of the Study

(i) To establish whether there is any cultural knowledge concerning heat among the students of the Kikuyu ethnic community and how such knowledge interacts with the accepted science.

Literature Review

'Heat' in Science Education

Ideas about heat are prevalent throughout science courses and will have been encountered by most if not all secondary school students in Kenya. The current 8-4-4 primary school science curriculum indicates that the topic of heat is taught to primary school pupils from Standard Five (Grade 5) (Kenya Institute of Curriculum Development (KICD), 2015). In secondary

schools, students are introduced to 'temperature' and 'expansion' in Form One (Grade 9) and to ideas about the 'modes of heat transfer' in Form Two (Grade 10). At these two levels, ideas about heat in terms of the effects of heating on matter are covered. 'Quantity of heat' as evidence of interaction between particles within the context of a vigorous treatment of particle dynamics theory is taught in Form Three (Grade 11) (KICD, 2016). At this level, quantitative aspects of heat, for example, 'latent heat', 'heat capacity' and 'specific heat capacity' as well as the qualitative aspects, for example, 'cooling by evaporation' are covered. This implies that learners are exposed to kinetic theory of matter in Form Three.

Zemansky (2000) describes 'heat' as a mysterious quantity which energy becomes during transfer from matter to matter but which cannot exist between matter. The energy is subsumed into the energy of the constituent particles. According to Summers, (2003), 'heat' cannot exist within a body but can only manifest as energy transfers from one body to the next. When transfer ceases heat as a phenomenon has no further existence. As the energy transfers, it can be thought of as heat but when the transfer is complete, and the bodies are separated, only the internal energies of the bodies exist. Internal energy cannot be equated to heat. It is the aggregate of the kinetic and potential energies of the atoms in the body.

The usage of the word 'heat' in science classrooms is an incongruous mix of science and everyday experience. Zietsman and Naidoo (2007) argued that caloric notions of heat have been infused in African learners due to reliance on instructional techniques and resources fashioned from the West. For example, Zietsman and Naidoo noted the following paragraph in a Physics textbook by Duncan (2000):

> "Temperature decides the direction in which heat flows just like pressure does in liquid flow. Heat flows from a body at a higher temperature to one at a lower temperature. A liquid flows of its own accord from a higher pressure to a lower pressure" (p. 123).

It is not difficult to imagine how 'heat flow' leads to conceptualization of 'heat' as having material characteristics.

Influence of Cultural Environment on Students' Conceptions of Heat

In non-Western societies, it is increasingly becoming clear that understanding the contribution of traditional culture's world view to science learning is significant to the adoption of science, its methods and values (Ogawa, 2006; Ogunniyi, 2006, Cobern, 2003). As Cobern notes, in developing countries there is need to ask questions about world-view and the compatibility of various non-Western world views with modern science. This issue of cultural context with reference to African countries is also articulated by Morris (2003) who notes that education does not take place in a cultural vacuum but occurs against the background of a view of the world and humanity's society.

Science then must be studied in relation to socio-cultural variables and traditional world-views if effective integration of the traditional world-view and the scientific world-view is to take place (Solomon, 2007). Before such integration takes place, it is worthwhile to ask how specific aspects of indigenous culture interact with science, in other words, are there areas within the African cultural context that interact in a manner complimentary to the accepted scientific world-view?

It is well documented that there are prevalent metaphors involving heat amongst many African peoples. Schapera (2009), Hammond-Tooke (2001) and Verryn (2001) found such metaphors among the Sotho people of Southern Africa. The metaphors are well grounded in the cultural and physical environments of the people. Among the Kikuyu, there is a belief that 'Coolness is good' (implying health and social harmony) while the converse 'hot is bad' (implying sickness and social disharmony). This is even reflected in the popular Kikuyu greeting "*Wĩ Mũhoro*?" which directly translates as "are you cool?" or the metaphor to describe a very bad situation, "*nĩ kũhiũ mũno*" which directly translates as "it is very hot". This is probably as a result of the people's basic concern for the climate. The Kikuyu are predominantly farmers and a cool wet climate to them means bumper harvest, while on the other hand a hot dry climate means harsh conditions leading to poor harvest, drought and famine.

Lynch (2005) observed that in a society which is much closer to subsistence demands, it is not surprising that the notion of world-view will incorporate the cultural values revolving around the social and physical environment of the society. Hewson and Hamlyn (2004) observed metaphorical heat conceptions among the Sotho people of Southern Africa which they attributed to the harsh environmental conditions surrounding them. As Lakoff and Johnson (2001) pointed out, all metaphors are grounded in experience. This study sought to find out whether such metaphors concerning heat exist in students' explanations of real life experiences among the Kikuyu people living in Nyandarua County. Such experiences include birth, pregnancy, menstruation, sickness and a variety of situations involving negative feelings, for example anger, impatience and anxiety

Methodology

The study was generally exploratory survey. Surveys are efficient in obtaining information about people's ideas (Borg & Gall, 2012). The study aimed at finding out the kind of conceptions that learners have about heat and whether the conceptions are at variance with the accepted science. It was therefore important to use subjects that had not formally been introduced to the kinetic theory of matter. For this reason, Form One learners were deemed appropriate. Aspects of the theory are formally introduced to learners in Form Three (KICD, 2016). To ensure that the respondents were residents of Nyandarua County which is predominantly occupied by the Kikuyu ethnic community, only Sub-county level of secondary schools were involved.

The accessible population therefore comprised all Form One students in public secondary schools of the Sub-county category in Nyandarua County. The sample size was determined statistically using the formula provided by Mugenda and Mugenda (2013). Out of the accessible population of 3947, 494 students were randomly selected to take part in the study.

The instrument comprised a questionnaire whose aim was to establish whether or not, students use metaphorical heat conceptions to explain various life experiences. A real life situation involving people and/or animals was described to the students in the first part of each item and then they were asked to state whether the people and /or animals in the situations could be described as 'hot'. They were then asked to explain their answers. The described life situations were those that have some cultural significance among the Kikuyu people. They included: circumcision, birth, pregnancy, sickness among others.

A pilot study was carried out using 48 students who were not part of the main study sample. The purpose of the pilot study was to collect data that would be used to determine the range of the responses expected in the main study as well as assess the instrument for validity and reliability. The items in the questionnaire were reviewed for clarity and systematically refined before use in the main study.

Analysis of students' of students' responses indicated that those who accepted that the people or animals in the given situations could be described as 'hot' could be grouped into two categories: biological and behavioral. Biological responses included those that used the concept 'hot' to describe a state of increased body activity or metabolism. Behavioral responses were those that used the concept 'hot' to describe a change in behavior of the people/animals. These categories were used as the basis for data analysis. Data analysis involved determining the frequencies of the two categories of responses. Results were presented in form of tables.

Results and Discussion

The study sought to establish whether students use cultural metaphors concerning heat to explain various real life situations. The results are presented in the sections that follow:

Anger

Item number 1 required the students to either agree or disagree that the term 'hot' could be used to describe an angry person and if in agreement, to explain their answer. The distribution of the types of responses given by the students is given in Table 1

Table 1: ***Distribution of Students' Responses on the Use of the Term 'Hot' to describe an Angry Person (N = 494)***

Category or Response	Frequency	Percentage
Behavioral Changes	268	54.2
Biological Changes	119	24.1
Negative	86	17.4
Non-respondents	21	4.3

From the results in the table 1, 78.3% of the students were in agreement. Of these, 69.3% subscribed to behavioral changes while 30.7% subscribed to biological changes. Those who were in disagreement comprised 17.4% while those who did not respond to this item comprised 4.3% of the students.

Cow on Heat

Item number 2 required students to either agree or disagree that a cow which is on 'heat' can be described as 'hot' and if in agreement to explain their answer. The distribution of the type of students' responses is given in Table 2:

Table 2: ***Distribution of Students' Responses on the Use of Term 'Hot' to Describe a Cow on Heat (N = 494)***

Category or Response	Frequency	Percentage
Behavioral Changes	245	49.6
Biological Changes	116	23.5
Negative	101	20.4
Non-respondents	32	6.5

The results show that those in agreements comprised 73.1% while those in disagreement comprised 20.4% of the students. Non-respondents to this item comprised 6.5% of the students. Of those in agreement, 67.9% subscribed to behavioral while 32.1% subscribed to biological changes.

Initiation

Item number 3 required students to either agree or disagree that a group of boys about to face the circumciser during an initiation ceremony can be described as 'hot' and if so to explain their answers. The distribution of the types of students' responses is given in Table 3:

Table 3: ***Distribution of Students' Responses on the Use of the Term 'Hot' to Describe Boys Involved in an Initiation Ceremony (n = 494)***

Category or Response	Frequency	Percentage
Behavioral Changes	228	46.2
Biological Changes	137	27.7
Negative	87	17.6
Non-respondents	42	8.5

From the results, 73.9% of the students were in agreement while 17.6% were in disagreement. 8.5% of the students did not respond to this item. Of those who were in agreement, 62.5% gave explanations that were categorized as subscribing to behavioral changes while 37.5% were categorized as subscribing to biological changes.

Bess Attack

In item number 5 the subjects were asked whether they would describe students' under bees attack as 'hot'. If 'yes' they were asked to explain their answers. The distribution of students' responses is given in the Table 5:

Table 5: ***Distribution of Students' Responses on the Use of the Term 'Hot' to Describe Students Under Bees Attack (N = 494)***

Category or Response	Frequency	Percentage
Behavioral Changes	256	51.8
Biological Changes	147	29.8
Negative	70	14.2
Non-respondents	21	4.2

Results show that 81.6% of the students were in agreement while 14.2% disagreed that the students can be described as 'hot'. 4.2% of the students did not respond to this item. Of the students in agreement, 63.5% subscribed to behavioral changes while 36.5% subscribed to biological changes.

Menstruation

Item number 6 asked the students whether menstruating girls can be described as 'hot' and if 'yes', they were asked to explain why they said so. The distribution of their responses is given in Table 6:

Table 6: ***Distribution of Students' Responses on the Use of the Term 'Hot' to Describe Menstruating Girls (N = 494)***

Category or Response	Frequency	Percentage
Behavioral Changes	199	40.3
Biological Changes	179	36.2
Negative	85	17.2
Non-respondents	31	6.3

Results in the table show that 76.5% students were in agreement while 17.2% were in disagreement that menstruating girls can be described as hot. 6.3% of the students did not respond to the item. 52.6% of those who were in agreement subscribed to the category of behavioral changes while 6.3% subscribed to biological changes

Active Person

Item number 7 asked students whether an active and hardworking person can be described as 'hot' and if 'yes' to explain why they said so. The distribution of students' response is given in the Table 7:

Table 7: ***Distribution of Students' Responses on the use of the Term 'Hot' to Describe an Active Person (N= 494)***

Category or Response	Frequency	Percentage
Behavioral Changes	301	60.9
Biological Changes	110	22.3
Negative	61	12.3
Non-respondents	22	4.5

The results in the table show that 83.2% of the student responded in the affirmative while12.3% responded in the negative. 4.5 % of the students did not respond to the item. Of those who responded in the affirmative, 73.2% were categorized as subscribing to the behavioral while 26.8% were categorized as subscribing to biological changes.

Impatience

Item 8 asked students whether an impatient person due to waiting for long time can be described as 'hot'. If 'yes' they were asked to explain their answers. The distribution of students' responses is given in Table 8:

Table 8: ***Distribution of Students' Responses on the Use of the Term 'Hot' to Describe an Impatient Person***

Category or Response	Frequency	Percentage
Behavioural Changes	291	58.9
Biological Changes	91	18.4
Negative	73	14.8
Non-respondents	39	7.9

From the results it can be seen that 77.3% of the student agreed while 14.8% disagreed. Non-respondents in this item comprised 7.9% of the students.76.2% of the students who replied in the affirmative gave explanations categorized as subscribing to behavioral changes while 23.8% were categorized as subscribing to biological changes.

Discussion

Analysis of students' responses show that metaphorical heat conceptions are present albeit in varying amounts in students from Nyandarua County. These results can be viewed in the context of the students' cultural belief concerning heat. The social and economic life of the Kikuyu people appears to have given rise to a metaphor concerning heat. The people in this area are predominantly small scale farmers. For this reason climatic conditions are of special concern to them and 'heat' pervades many aspects of their lives.

Among the Kikuyu people there is a belief that 'coolness is good' and the converse 'hotness is bad'. There is a popular Kikuyu greeting *"wĩ mũhoro*" which means "are you well?" but directly translates to "are you cool?" On the other hand a volatile situation is usually described as 'hot'. This is exemplified by the popular Kikuyu phrase "*kũhiũhĩte ta thathi wa mũnyuko*", which directly translates as the "the situation is as hot as the soup of a bony animal." This could be used to explain why most students described the people or animals in situations involving negative feelings such as anger, impatience and others as 'hot'.

The Kikuyu people associate the state of increased physical activity, for example, vigor to the concept of 'hot'. A person who is quick with his hands is usually said to have 'hot hands' (*moko mahiũ*). There is also a popular saying among the people that "*werũ ũkwenda mbĩa hiũ*", which directly translates as "the wilderness requires a hot rat". It means that for survival, one has to be very active. The Kikuyu word "*hiũha"* has two meanings: 'get hot' and 'hurry up'. This logically fits with the kinetic theory of matter which involves increased random movement of particles of matter when heated.

Whereas no direct casualty can be attributed to this fact as far as the present study is concerned, it would appear that there is an inferential logical fit between the metaphorical conceptions and the non-prevalence of caloric heat conceptions among learners in Africa. As noted by Shumba (2005), this could be one area where indigenous thought interacts in a manner complementary to the accepted scientific theory.

Conclusions

The results of the study indicates that students belonging to the Kikuyu ethnic community resident in Nyandarua County bear metaphorical heat conceptions which are to a large extent in harmony with the kinetic theory of matter. These conceptions are a product of the cultural knowledge of the community concerning heat and the results show they are acquired before formal study of the theory. This suggests that children from the Kikuyu ethnic community are at a relative advantage compared to their counterparts in the Western countries where massive caloric conceptions of heat have been found among learners. By extension, this implies that learners in the County do not have to unlearn outdated notions of heat before being formally introduced to the contemporary kinetic theory of matter to explain physical phenomena associated with heat. The features of their knowledge can be quite easily reconciled with the theory.

Recommendations

Based on the results, the study recommends that there is need to investigate aspects of indigenous knowledge that interacts in a manner complementary to the accepted science. Such knowledge should then be filtered and integrated into the science curricula of schools. For example, further research could be carried out to establish whether the cultural metaphor concerning heat among the Kikuyu ethnic community found in this study could apply to other African communities in Kenya. If so, the knowledge could be harmonized with the scientific view and integrated in the science curriculum so that learners see science as part of their culture. As observed by Shumba (2005), although we seek out science in books, it may already be existing in our culture, only that it is not formally documented.

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