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Ngozika Mbajiorgu & Innocent Anidu

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Non-Western students' causal reasoning about biologically adaptive changes in humans, other animals and plants: instructional and curricular implications

Ngozika Mbajiorgu[a] and Innocent Anidu[b]

[a]Department of Science and Computer Education, Enugu State University of Science and Technology, Enugu, Nigeria; [b]Department of Science Education, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

ABSTRACT
Senior secondary school students ($N = 360$), 14- to 18-year-olds, from the Igbo culture of eastern Nigeria responded to a questionnaire requiring them to give causal explanations of biologically adaptive changes in humans, other animals and plants. A student subsample ($n = 36$) was, subsequently, selected for in-depth interviews. Significant differences were found between prompts within the prompt categories, suggesting item feature effects. However, the most coherent pattern was found within the plant category as patterns differed for the mechanistic proximate (MP) reasoning category only. Patterns also differed highly significantly between the prompt categories, with patterns for teleology, MP, mechanistic ultimate and don't know categories similar for plants and other animals but different for the human category. Both urban and rural students recognise commonalities in causality between the three prompt categories, in that their preferences for causal explanations were similar across four reasoning categories. The rural students, however, were more likely than their urban counterparts to give multiple causal explanations in the span of a single response and less likely to attribute causal agency to God. Two factors, religious belief and language, for all the students; and one factor, ecological closeness to nature, for rural students were suspected to have produced these patterns.

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Introduction

In the past, much of biology instruction was concerned with explanations of conceptual inventions. Recently, attention has been drawn to the mode of inference used by students, but very little attention has been given to the causal mechanisms adopted by these students in making causal attributions (Russ, Scherr, Hammer, & Mikeska, 2008). Yet, studies in folk biology have demonstrated that children develop some knowledge of biological processes very early in life (e.g. Legare & Gelman, 2009). This knowledge has been found to be

CONTACT Ngozika Mbajiorgu nmbajiorgu@esut.edu.ng Department of Science and Computer Education, Enugu State University of Science and Technology, Enugu, Nigeria

weak (Hatano & Inagaki, 1994; Inagaki & Hatano, 2008) because young children lack adequate knowledge of mechanistic causality.

Inagaki and Hatano (2008) found that young Japanese children prefer vitalistic causality to intentional or mechanistic causality for biological phenomena; however, as the children grow older, their preference change to mechanistic causality but such changes, they claim, do not denote that older children and adults rely exclusively on mechanistic views for biological understanding. Hatano and Inagaki's (1994) claims were confirmed among English and Australian samples in the replication of their study by Morris, Taplin, and Gelman (2000). It is, however, believed that secondary school students have developed some knowledge of causal mechanisms over the years (Inagaki & Hatano, 2008). The understanding and use of mechanistic causality, however, require fundamental restructuring of biological knowledge, which is enhanced not only through biology instruction but also through watching TV, reading books, learning and using biological words and noting their implications (Inagaki & Hatano, 2008). This suggests that understanding biological causality could be culture-dependent, although it is a universal phenomenon (Geerdts, Van de Walle, & Lobue, 2015; Hatano & Inagaki,1994; Hatano et al., 1993; Herrmann, Waxman, & Medin, 2010; Inagaki & Hatano, 2006; Inagaki & Hatano, 2008; Johnson & Carey, 1998; Leddon, Waxman, Medin, Bang, & Washinawatok, 2012; Lindemann-Matthies, 2005; Medin & Atran, 2004; Medin, Waxman, Woodring, & Washinawatok, 2010; Tarlowski, 2006).

There is considerable evidence suggesting that the stages of development of an individual or the culture of an individual influences his/her view of causality. Legare and Gelman (2009, pp. 357–358) noted that 'research on biological reasoning provides evidence for … cross-cultural universalities, but also suggests potential cultural influences and specificities', whereas Peng and Knowles (2003, p. 1273) argued that these cultural influences are limited in the domain of physics since 'research … suggests that the perception of physical events is largely "hardwired" and innate and might, therefore, be resistant to the influence of culture'. This is unlike the domain of biology where efforts are made to accommodate different causal levels. Evans (2008, p. 275) noted that in biology, 'evolutionary causes are seen as critical links in a naturalistic causal chain set in motion by God', thus making biological causality susceptible to cultural influences, with God often considered as the first cause. Most of the studies on understanding of causality in the domain of biology (e.g. Hatano & Inagaki, 1994; Inagaki & Hatano, 2008; Medin et al., 2010; Southerland, Abrams, Cummins, & Anzelmo, 2001; Tarlowski, 2006) were conducted in the Western world or industrially developed nations. The participants are by no means representative of the generality of the global student population.

A good understanding of biological causality across cultures could inform curricula provisions, especially in the Third World countries where the practice is to reproduce curricula meant for Western students. This is, especially, critical because Ojalehto, Waxman, and Medin (2013, p. 168) argued that children and indigenous adults 'whose ecological expertise surpasses that of most Western educated adults, remain unclear about causal relations underlying natural phenomena', often endorsing intentional causality, with multiple causal attributions, over mechanistic causality. This, they argue, reflects a deep understanding of relational and deictic dependencies rather than theistic intentional functions. In other words, it does not suggest an understanding that nature was designed for a purpose; rather, it suggests a greater understanding of the relationships among living things and the environment.

Mbajiorgu (2000), however, did a study on Nigerian secondary school students' reasoning about genetic phenomena. She categorised the students' responses into four: scientific, spiritist, common sense conception and naturalistic explanations. The students were more likely to use scientific explanations in proximate causal attributions than they were in distal or ultimate causal attributions. For the latter, they were more inclined to make spiritist attributions. To enable comparability, this paper explores the causal explanations of some biologically adaptive changes in living things given by non-Western students from the Igbo culture – using Tamar and Zohar's (1991) categorisation scheme – because this captures the categories of Inagaki and Hatano (2008) (mechanistic, vitalistic and intentional) as well as that of Mbajiorgu (2000), in order to determine the extent of the universality as well as the role of culture on students' understanding of biological causality.

Tamir and Zohar (1991) identified and described seven major categories of responses based on students' reasoning patterns. This categorisation of causal reasoning has been used in many studies; for instance, Southerland et al. (2001) used these to explore two different perspectives of the nature of students' biological knowledge structures. They found that students' use of mechanistic explanations, as well as the tendency to use more than one explanation in a span of a single response increased with an increase in age. Many theologians and some scientists have tried to accommodate a multi-causal level by placing God as the first cause in a causal chain, with mechanical causes as critical links (Evans, 2008).

Culture and biological reasoning about humans, other animals and plants

Research evidence (Carey, 1985; Hatano et al., 1993; Inagaki & Hatano, 2008; Medin et al., 2010; Ross, Medin, Coley, & Atran, 2003; Tarlowski, 2006; Waxman, Herrmann, Woodring, & Medin, 2014) shows that culture and context have an effect on how children and indeed individuals reason about different aspects of biological entities. A number of studies have explored the differences in reasoning about humans, other animals, plants and inanimate objects, and how culture might have an influence on these reasoning patterns. Many of these studies looked at young children's naïve biology (e.g. Inagaki & Hatano, 2006; Medin et al., 2010) and focused on properties and categorisation of these entities (e.g. Hatano et al., 1993). They conclude that cross-cultural differences indeed exist in the understanding of different aspects of biological entities. For instance, in the study of Hatano et al. (1993), it was found that children of all ages studied and from different cultures understood that humans, other animals, plants and inanimate entities were different types of things, with different properties. They were highly accurate about the properties of humans, less accurate about other animals and inanimate objects and least accurate about plants. They also found that Israeli children least attributed properties of living things to plants, whereas Japanese children were more likely to attribute properties of living things to inanimate entities. U.S. children had the most accurate scientific understanding of different entities.

The inability of students and individuals to understand plants has been explored and demonstrated by biology educators over the years (Wandersee & Schussler, 2001). They posit that earlier studies adduced the reasons to 'zoo-chauvinistic introductory biology instructors, zoocentric examples used to teach basic biological concepts and principles, hyper-technical and uninteresting botany lessons, and under-emphasis (or utter neglect) of plants in students' biological laboratory and field experiences' (p. 3), and they propose a new theory '*plant blindness*' to explain the phenomenon. *Plant blindness* places emphasis on human perception and visual cognition. Lindemann-Matthies (2005) in his study demonstrated that interest and knowledge of plants and other animals can be enhanced through exposure to experiences that feature these entities. More recent studies have anchored reasoning and appreciation of humans, other animals and plants as biological entities on experience (Medin et al., 2010; Tarlowski, 2006; Waxman et al., 2014), leading to the suggestion that context represents a robust influence on individuals' reasoning about different biological entities.

The place of context in biological reasoning has indeed been explored by researchers and science educators. For instance, Nehm and Ha (2011) found robust contextualisation patterns when they worked with 1200 open-response explanations of evolutionary change – supporting the claim that contextuality and indeed physical contexts influence how people respond to biological tasks and reason about biological entities and phenomenon, whereas Evans (2001) concluded that cognitive factors interact with contextual factors to ensure the existence of culturally valued beliefs and reasoning in subsequent generations.

Interest in the relationship between culture and biological reasoning arose from the work of Carey (1985). She found that children have an anthropocentric view about biological entities. Using inductive reasoning tasks, she found that children generalise from humans to non-human animals, but made fewer generalisations from non-human animals to humans and other non-human animals. She also found that for older children and adults, reasoning about animals is organised around the concept of animal as an inclusive concept for humans and non-human animals. Medin et al. (2010) replicated the study with subjects from urban and rural areas. Their work suggested that culture and experience have a greater influence on young children than on older children. They speculate 'that it may be nearly universal that young children's experience with humans outweighs their experience with non-human animals, and this experience may lead them to privilege humans as an inductive base' (Medin et al., 2010, p. 5). Other results from their experiments led them to conclude that cross-cultural and experiential differences represent robust differences between different communities. In another study, Leddon et al. (2012) adopted a cross-cultural developmental perspective to study children's understanding about humans, other animals and plants. Their findings revealed that children of all ages and from different communities consistently deny that humans are animals. A number of researchers have contributed to the understanding of reasoning from a developmental and so an obligatory perspective and reasoning as an acquired cultural model (Carey, 1985; Geerdts et al., 2015; Hatano et al., 1993; Leddon et al., 2012; Medin et al., 2010; Ross et al., 2003; Tarlowski, 2006; Waxman et al., 2014). This study engages 14- to 18-year-old Igbo secondary school students. It is expected that at this age they appreciate humans from an inclusive perspective as one animal kind among many. The students' understanding of causal attributions of biologically adaptive phenomena relating to humans, other animals and plants and how culture and ecological closeness to nature might have impacted these understandings were explored.

The Igbo culture

This study was carried out among the Igbo students of eastern Nigeria. The Igbo tribe is one of the three major tribes that make up the nation Nigeria. The Igbo people have a religious outlook to life (Chukwuezi, 2008). Their reality is divided into two interacting spheres: the physical and the spiritual. These two interact in such a way that spiritual and cosmic forces are perceived to influence the human world. According to Nwoye (2011), the human world is three-tiered: (1) the Heavens – the place of abode of the supreme being, God, and other deities as well as other heavenly hosts; (2) the Earth is inhabited by humans who are also considered to be spirit beings and Earth deities, minor divinities and nature forces; and (3) the Underworld is inhabited by ancestral spirits, other disembodied spirits and personified forces (see Figure 1).

Most of these spirits and forces are malevolent and influence the Earth and humans as much as the divinities and deities of the sky do. There is, therefore, a battle between good and evil. This is played out among the humans, with nature being the available tool or weapon for this battle. Events are seen in relation to the interaction of these spirits, deities and their influence on humans and their general well-being, as well as on the physical world. For instance, if there is drought, it is seen as a judgement on man for some reasons. The human being is central to every activity and event. This was also claimed to be true for Turkey, another non-Western culture, by Yorek, Şahin, and Aydın (2009) working on students' construction of the life concept for animals and plants.

This religious outlook predisposes individuals from this culture to make causal attributions with non-scientific aetiological explanations. For instance, Nzewi (2001) explored culturally defined symptoms of 100 children who were believed to be suffering from *ogbanje* (a malevolent spirit that is believed to possess sufferers). This is a phenomenon where a couple may lose their children at infancy. Nzewi found a high degree of concordance between culturally accepted symptoms of this malevolent condition, *ogbanje*, and

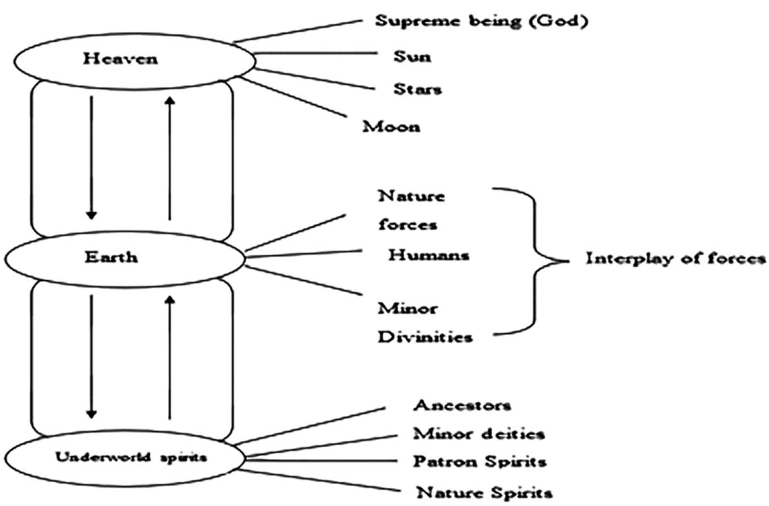

Figure 1. Diagrammatic representation of the Igbo culture. Adapted from Chukwuezi (2008).

the symptoms of sickle cell disease. Despite this study and other similar studies, it is difficult for members of this culture to accept sickle cell disease as an explanation of *ogbanje.* Okoro (1975) also investigated causal attributions relating to 1000 albinos from this culture. It was found that their causal attributions did not associate this condition with inbreeding and/or heredity; rather, their traditional views referred to non-scientific aetiological theories including punishment from the gods, conception during menstruation, frightening sights during pregnancy and so on as causal factors. In the present study, this understanding is taken further by exploring causal reasoning related to biologically adaptive features in humans, other animals and plants among secondary school students from this (Igbo) culture.

Purpose of the study

Interest in the role of culture in the understanding of biological entities began with the work of Carey (1985). Much of this work focused on the mode of inference, categorisation and properties of these entities and led to the conclusion that experience and culture mediate these understandings and that differences indeed exist in the mode of inference, categorisation and properties with regard to humans, other animals and plants. As such, there is a question of whether similar differences exist when making causal attributions regarding these entities and whether such differences reflect the cultural context of individuals. And of particular importance, what are the instructional implications of any findings about the present set of students' conceptions? We, therefore, explored the nature of some Nigerian senior secondary school students' causal reasoning about humans, plants and other animals and, in general, probed to see how culture might contribute to the patterns observed.

Methods

Participants

Senior secondary students ($N = 360$) from the Igbo culture of eastern Nigeria participated in this study. Six schools, with 60 students from each, were selected for the study through random sampling. Three of the schools were randomly selected from an urban location (Enugu City) and three from a rural location (Udi Educational Zone of Enugu State). The rural area is characterised by a lack of tarred roads, pipe-borne water and irregular electricity from the national grid. The population is predominantly agrarian and domestic animals are reared by most families. Media (web and mass) presence is very minimal. Family settlements are interspersed by vegetation and farmlands. In the urban location, conditions are reversed. In all, 99.9% of students from eastern Nigeria are Igbos, and students at this stage are generally between 14 and 18 years.

At the senior secondary school levels in Nigeria, students are required to take at least one of the three science subjects (biology, physics or chemistry) and 99% of them opt for biology. All the students involved in this study were receiving biology instructions. Studying this group of students will contribute to the knowledge about the influence of culture on students' causal understanding of phenomena (biologically adaptive changes) considered universal.

There exists a national biology curriculum (Appendix 1). All students (urban and rural) are taught using this same curriculum with which they are prepared for a regional (West African Senior Certificate) and a national (National Examination Council) examination.

Research instrument

The instrument used for this research was the questionnaire developed by the authors. The principle of Ordered Multiple-Choice items was adopted, in which the ‘distractors’ reflect viable alternative conceptions. Eighteen students from two schools, other than the ones who participated in this study, were asked to give free responses to questions related to six prompts used in this study (Figure 2) and their responses were analysed for categories. Three pairs of prompts addressed inter-category reasoning and two prompts were used to determine the differences in reasoning patterns for each prompt category. The prompt categories in this study are humans (an albino and a developing human foetus showing umbilical cord), other animals (a species of grasshopper that exhibits *seasonal variation in colour* – green in the rainy season, and brown in the dry season; and a scorpion with *prominent pedipalps* and *the stinger*) and plants (a cactus plant with s*pines* and a fluted pumpkin shoot system with *tendrils*).

Plate	Title
A	A cactus plant with s*pines*
B	Fluted Pumpkin shoot system with *tendrils*.
C	A specie of grasshopper that exhibits *seasonal variation in colour* (green in rainy season, and light brown in dry season).
D	A Scorpion with *prominent pedipalps* and *the stinger*
E	A developing human foetus showing the *umbilical cord*.
F	An *albino*

Figure 2. Coloured picture plates showing the different prompts.

The categorisation was guided by Tamir and Zohar's (1991) categorisation scheme. They defined anthropomorphic (A) reasoning as a reasoning category in which explanation is based on human attributes as the causal agent for changes seen in non-human organisms; it also includes an explanation of humans and non-human organisms as being able to cause the desired biological change by themselves. Teleological (T) reasoning is explanation based on need as being the agent of biological change, or the agent in determining the nature of biological phenomena and it assumes that a feature exists for a purpose (Kallery & Psillos, 2004; Keleman, 1999). Bourne (2011) posited that teleology was the key to explanations of biological phenomena before the understanding of causal mechanisms and argued that it still is important in present-day causal explanations. Mechanistic proximate (MP) reasoning is the reasoning category in which a specific physiological/biological or external agent is identified. Typically, such an explanation describes just the individual being observed and does not consider the entire group or population of organisms. Mechanistic ultimate (MU) category is the reasoning category in which a long-term (generally, genetically based) agent is identified. This is the evolutionary reasoning category because such an explanation describes the evolution of the entire population of organisms, and not just an individual. Predetermined (P) reasoning category is one in which the causal agent of the biological phenomenon is identified as a supernatural being, such as God, a god, a spirit or an unknown supernatural agent. Blended (B) category is the reasoning category in which the respondent gives an explanation that fulfils the requirements of more than one of the above reasoning categories within the span of a single response. The last 'don't know' (DK) category is where the respondent indicates he or she does not know the answer.

The categories that emerged from the free responses were then used as the Ordered Multiple-Choice options to the three questions asked regarding each prompt. Since these represented the reasoned viewpoints of students, they were not scored; rather, nominal values were assigned to them for the purposes of analysis (see Appendix 2 for sample questions).

The questionnaire was face-validated by three experts, respectively, from the fields of biology education, measurement and evaluation, and educational psychology to check for language accuracy and complexity and if indeed a valid mechanistic viewpoint was accommodated. The draft questionnaire was given to three researchers working in the area of reasoning patterns. They were required to code each alternative to the three questions for each prompt using the Tamir and Zohar categorisation scheme. An interrater reliability test was conducted using Kendall's W to determine the extent to which the researchers agree in their assignment of alternatives to a category. The coefficient of concordance was 0.944, indicating that the questionnaire could be used with a high degree of accuracy with this group of students. The questionnaire was then administered to 20 students from a school in the same area that was not part of the sample. This was to check if each alternative represented a viable viewpoint. All alternatives were selected by some students, indicating that they indeed represented viable viewpoints.

Students were expected to select from the pool of seven reasoning categories the response that best represented their causal understanding of the biologically adaptive phenomenon under consideration. The responses and the data from the interview were used to explore students' causal understanding of biologically adaptive phenomena among the three prompt categories (human, other animals and plants), as well as the role of culture (represented by rural and urban residences) on these understandings. A student subsample (n = 36) was, subsequently, selected for in-depth interviews using an interview protocol (see Appendix 3).

Data analysis

Three 2×7 chi-square tests were done to test for differences in reasoning patterns between specific prompts within each prompt category. The pooled data were then subjected to a 3×7 chi-square test to test if patterns differed significantly between the three prompt categories. This was followed by three additional *post hoc* chi square tests to compare patterns between pairs of prompt categories. This is in order to determine for which specific type(s) of causal reasoning there are significant differences between each pair of prompt category under consideration. Finally, a multivariate chi-square test was performed. This involved the response variable (reasoning patterns), the explanatory variable (prompt category) and a control variable (location). The probability level was set at $p < .05$, which was then corrected using the sequential Bonferroni test for the different partial tables. For analysis with 6 degrees of freedom, probability was set at $p < .004$, and for those with 12 degrees of freedom, probability was set at $p < .002$. This is in order to counteract the problem of multiple statistical/pairwise comparisons. To determine whether there were significant associations between reasoning patterns, prompt category and location, adjusted p-values were calculated for each pairwise comparison. The interview data were then used to explain the patterns emerging from the chi-square tests.

For the analysis of differences between prompts within each prompt category, a total of 2160 responses were obtained from the 360 students. For the pairwise analysis between prompt categories, a total of 4320 responses were obtained, and for the multivariate analysis involving the prompt categories and location, the analysis was done based on 6480 responses.

Results

Reasoning patterns between pairs of prompts in each prompt category

The analysis of reasoning patterns between the pairs of prompts within each prompt category revealed that for plant prompts, there was a significant difference in the use of MP explanations only ($\chi^2 = 94.09$, df = 6, $n = 2160$, $p < .0000$). The students were less likely to use MP reasoning for the fluted pumpkin than for the cactus plant. For other animal prompts, patterns differed significantly in the use of teleological (T), anthropomorphic (A) and MP explanations. The students were more likely to use teleological and anthropomorphic explanations (T $\chi^2 = 56.25$, df = 6, $n = 2160$, $p < .0000$; A $\chi^2 = 54.76$, df = 6, $n = 2160$, $p < .00000$) for the scorpion than for the grasshopper, and more likely to use MP ($\chi^2 = 86.49$, df = 6, $n = 2160$, $p < .0000$) for the grasshopper than for the scorpion. Patterns also differed significantly between the albino and the foetus/umbilical cord prompts in the use of the teleological ($\chi^2 = 295.84$, df = 6, $n = 2160$, $p < .0000$), MU ($\chi^2 = 213.16$, df = 6, $n = 2160$, $p < .0000$) and MP ($\chi^2 = 106.09$, df = 6, $n = 2160$, $p < .0000$) explanations. A significantly higher number of students preferred teleology and MP explanations for the foetus and umbilical cord prompt and a significantly lower number explained albinism using the MU explanation.

The results indicate there are indeed strong context-effects (item features effects) in students' reasoning about causality among biological entities. Caution is, therefore, suggested when interpreting results from the pooled responses, although definite patterns emerged. Results based on the pooled responses may not be readily generalised as the typical pattern for the different prompt categories.

Levels of association between reasoning patterns and prompt types

Chi-square tests done to determine the levels of association between reasoning patterns and prompt type were significant at 0.000. This indicated that the patterns of causal reasoning differ highly significantly between the three prompt categories. Using the Bonferonni correction, the p value was set at .004. Adjusting the p value for all three combinations, it was found that a statistically significant ($\chi^2 = 54.76$, df $= 12$, $n = 6480$, $p < .0000$) lower number of responses than expected were made using teleology as the causal reasoning regarding biologically adaptive changes in humans, whereas the prediction of independence for teleology was true for other animals and plants.

There is also a significantly higher number of students from this student sample using the anthropomorphic explanations to make causal attributions for the plant category than is expected; and a significantly lower number using the anthropomorphic reasoning category to explain biologically adaptive changes in humans ($\chi^2 = 102.01$, df $= 12$, $n = 6480$, $p < .0000$). The percentage using this reasoning category for other animals is not statistically significant.

Other significant differences occurred in the use of MU and MP categories. The students were more likely to use MU reasoning and less likely to use MP reasoning for humans (MU $\chi^2 = 655.36$, df $= 12$, $n = 6480$, $p < .0000$; MP $\chi^2 = 219.04$, df $= 12$, $n = 6480$, $p < .0000$). The following conversation between a student and the interviewer shows a greater use of MU reasoning for a human prompt and a greater use of MP reasoning for an animal and a plant prompt.

Albinism

R: What do you call people with this type of complexion?
S: 'Anyali' (meaning albino).
R: Why is the person in this picture having this type of complexion?
S: It may be in the family lineage (**mechanistic ultimate**); or the person lacked some nutrients in the womb and this affected the skin colour (**mechanistic proximate**).
R: Is there any way she can correct her present complexion so that she becomes of normal skin colour?
S: No! even if she uses any cream, it will be artificial, and will not last.
R: Why?
S: It is a permanent thing (feature) in the girl.
R: Why is it permanent?
S: It is in their lineage (insistence on **mechanistic ultimate**); God created her like that (a return to God as first cause).

Seasonal Colour Change in Grasshopper

R: Why do you think the organism changes its colour?
S: Because it has to change it during the dry season.
R: Why does it change during the dry season?
S: To enable it hide in the dry leaves and dirt (**teleology**).
R: Does it turn brown at will?
S: No, the weather causes it to turn brown (**mechanistic proximate**).
R: Is it that it dries out like the leaves as a result of the dryness of the weather?
S: No, it is not dried out as is the case of leaves, it just changes colour as a seasonal change.

Fluted Pumpkin with Tendrils

R: Why do you think the plant has the tendrils?
S: For climbing up trees (**teleology**).
R: How do you think it developed them?
S: It developed through the stem (**mechanistic proximate**).
R: You also said the same for the cactus, that it developed them through the skin. Does that mean the skin and stem have the power to develop these things?
S: The tendrils and leaves developed in the same way, from the stem (**mechanistic proximate**).

Their use of MU and MP categories were similar for other animals and plants as a significantly higher number of students than expected used MP reasoning in explaining the biologically adaptive changes in other animals and plants (*Other Animals* $\chi^2 = 156.25$, df = 12, $n = 6480$, $p < .0000$; *Plants* $\chi^2 = 174.24$, df = 12, $n = 6480$, $p < .0000$), whereas a significantly lower number than expected used the MU category for other animals and plants (*Other Animals* $\chi^2 = 56.25$, df = 12, $n = 6480$, $p < .00005$; *Plants* $\chi^2 = 51.84$, df = 12, $n = 6480$, $p < .0002$).

Further difference was noticed in the use of the 'Don't Know' category, where a significantly ($\chi^2 = 49.00$, df = 12, $n = 6480$, $p < .0000$) higher number than expected used this reasoning category for the human category. No differences were found in their use of predetermined and blended categories among the three prompt types. The close association of other animals with plants (Figure 3 illustrates these patterns) is attested by the response given by one of the students:

R: Why do you think the grasshopper changes its colour during different seasons?
S: Because of the rain.
R: How is that?
S: Because it is a '**plant animal'**. During the rains it turns green and during the dry season, when there is little or no water, it dries out and turns brown.
R: Oh! Why do you say it is a 'plant animal'?
S: Because it has the characteristics of plants. It is green in colour.

Post hoc tests performed to test for which specific type(s) of causal reasoning there are significant differences between pairs of prompt categories under consideration (e.g. human vs plants) revealed that a significant association between reasoning patterns and prompt type was only noticed in the anthropomorphic category for plants and other animals ($\chi^2 = 28.09$, df = 6, $n = 4320$, $p < .00009$). There were no significant differences among the other reasoning categories as the null hypothesis of independence predicted.

The patterns for the human vs plant and the human vs other animal categories were similar. A statistically significant number of students were more likely than expected from this sample to explain biologically adaptive changes in humans using the MU

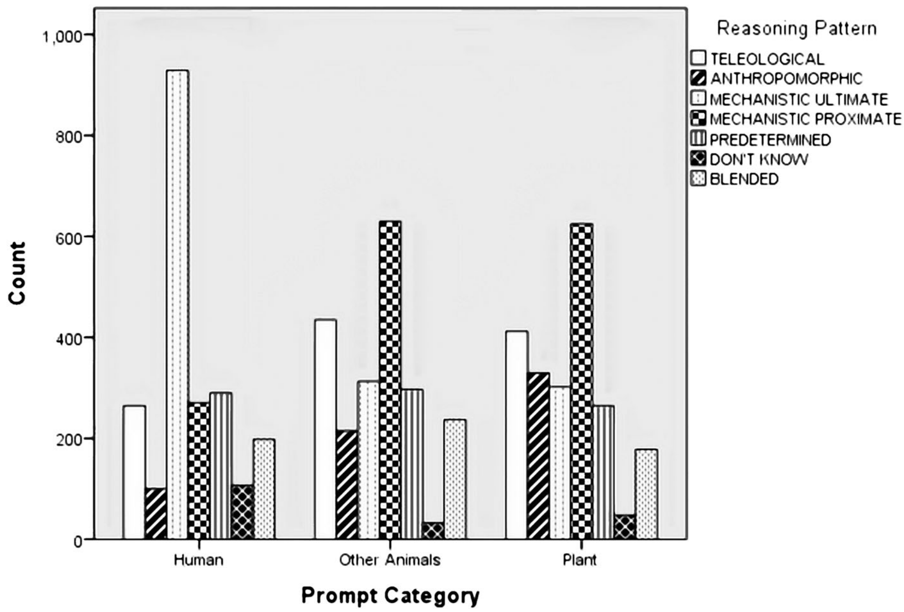

Figure 3. Percentage of students using each reasoning category among the three prompt categories.

reasoning category when compared to other animals and plants (*Human vs Other Animals* $\chi^2 = 428.49$, df = 6, $n = 4320$, $p < .0000$; *Human vs Plants* $\chi^2 = 445.21$, df = 6, $n = 4320$, $p < .0000$), where a significant lower number chose the MU category. On the other hand, a significant number was less likely to make causal reasoning using the teleological (*Human vs Other Animals* $\chi^2 = 49$, df = 6, $n = 4320$, $p < .0000$; *Human vs Plants* $\chi^2 = 38.44$, df = 6, $n = 4320$, $p < .0000$), anthropomorphic (*Human vs Other Animals* $\chi^2 = 44.89$, df = 6, $n = 4320$, $p < .0000$; *Human vs Plants* $\chi^2 = 136.89$, df = 6, $n = 4320$, $p < .0000$) and MP (*Human vs Other Animals*$\chi^2 = 179.46$, df = 6, $n = 4320$, $p < .0000$; *Human vs Plants*$\chi^2 = 176.89$, df = 6, $n = 4320$, $p < .0000$) categories for the human prompts, whereas for the other animal and plant prompts a significantly higher number than expected chose these three categories. There were no significant differences in their choice of predetermined and blended categories. A significantly higher number of students than expected (*Human vs Other Animals* $\chi^2 = 40.96$, df = 6, $n = 4320$, $p < .0000$; *Human vs Plants* $\chi^2 = 23.04$, df = 6, $n = 4320$, $p < .00008$) would rather not make a choice when they were not sure of the causal agent for the animal category (Don't Know), whereas a significantly lower number did the same for the other animal and plant categories.

Reasoning patterns between rural and urban students

The students were probed to see if location (urban and rural locations) had any influence on the preferred causal explanation employed in causal attributions regarding biologically adaptive changes in humans, other animals and plants. The results indicated that for the three pairwise comparisons, pattern of causal reasoning differed highly significantly between rural and urban students (*Human Prompt* $\chi^2 = 73.79$; df = 6; $n = 2160$, $p < .000$; *Other Animal Prompt* $\chi^2 = 127.52$; df = 6; $n = 2160$, $p < .000$; *Plant Prompt* $\chi^2 = 108.49$; df = 6; $n = 2160$, $p < .000$). This is illustrated in Figure 4.

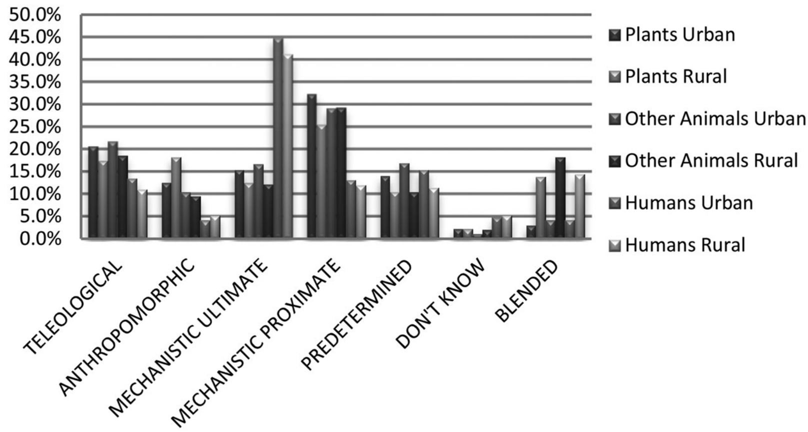

Figure 4. Percentage of urban and rural students' responses for each reasoning category.

Post hoc tests examining these differences between rural and urban students for each category of causal reasoning showed significant differences in the blended category only. This difference was obtained across the three prompt categories (*Human Prompt* $\chi^2 = 67.24$; df = 6; $n = 2160$, $p < .000$; *Other Animal Prompt* $\chi^2 = 108.16$; df = 6; $n = 2160$, $p < .000$; *Plant Prompt* $\chi^2 = 84.64$; df = 6; $n = 2160$, $p < .000$). A significantly higher number of students from the rural location made multiple causal attributions, in a span of one single response, regarding human, plant and other animal prompts, than would be expected from this student sample. There were no significant differences noticed for the other reasoning categories. Typical multi-causal reasonings are given below:

S: No. God designed it for the mother and the baby. Man is made in the image of God and God has designed every part of his body and this is passed from parents to children through the genes. (Blended)

S: The cactus has spines because it uses it to beautify itself as a flower. In addition, the thing helps the plant to reduce water loss, and spines help to protect the plant because it can pierce people's hand. God also created it to be like that. (Blended)

Since patterns of causal reasoning between rural and urban students were similar for all three pairwise combinations of prompt types, an analysis was done for the pooled data. Results showed that contrary to the independence predicted by the null hypothesis for all reasoning categories, there was a significant association (*Predetermined* $\chi^2 = 31.36$; df = 6; $n = 6480$, $p < .00002$; *Blended* $\chi^2 = 259.21$; df = 6; $n = 6480$, $p < .0000$) between location and students' use of the predetermined and blended categories for causal explanations. The urban students were more likely to use predetermined reasoning category than their rural counterparts. On the other hand, they were less likely than the rural students to use multiple causal attributions in explanation of biologically adaptive changes in humans, other animals and plants. There were no significant differences noticed for all other reasoning categories. The following is a typical conversation between the interviewer and a rural student:

R: How did the cactus plant get all these spines?
S: The body formed them. They grew out from the body (**mechanistic proximate**)
R: Why did the cactus have the spines?

S: God wants it to be like that. But they must have a function … Some say it uses the spines to kill witches and wizards, so we keep the plant in homes as flowers because it drives away witches and wizards. It also drives away rats, especially, witch rats (i.e. spiritual rats or 'oke amusu'). (**blended**)
R: Did this cactus plant think about the spines before it developed them?
S: I don't know, but it knows it has the spines, that's why it uses it against witches. (**anthropomorphism**)
R: Why do you think so/say so?
S: It has the spines from its creation/creator, so it knows it has the spines. (**predetermined**)

In other words, the spines were developed by the body (MP) because it wants to use it to kill witches (teleology). All this is because God created it to be so (first cause). Notice the blended explanation (in bold) and the cultural context of the response.

Discussion

Causal reasoning about humans, other animals and plants

The most coherent pattern of causal explanation emerged between the plant pair of prompts. This conclusion should be taken with caution as the two prompts presented for the plant category have features whose functions are easily discernible. Further studies need to be done to investigate the place of item feature effect on understanding of causal reasoning among biological entities. It appears that when the function of a feature is readily perceptible for other animals, as is the case for the scorpion, the students will reason in terms of need (teleology) and intent (anthropomorphism). For humans they would reason in terms of need (teleology) and vitalism (MP). Where the function of a feature is less discernible, the students reasoned in terms of biological predeterminism (MU) for humans and vitalism (MP) explanations for other animals. For within prompt category comparisons, therefore, responses differed for all three pairwise comparisons, supporting the claim of Nehm and Ha (2011) that contextualisation and physical context are important in biological reasoning.

Was the students' understanding of biological causality the same for the different prompt categories? Results of the study revealed that students maintained a distinction between the different entities as all the chi-square analyses yielded significant χ^2 values. However, the use of teleology, MP, MU and Don't know categories was similar for plants and other animals, but different for the human category. This indicates the students did not appreciate that humans go through the same evolutionary pathway as other animals and plants and may suggest that they do not perceive humans as one animal kind among many. This is in contrast to the findings of Carey (1985) and Medin et al. (2010), who claimed that older children have developed to appreciate the relationship between humans and other animals, but in line with the result from the work of Leddon et al. (2012) who demonstrated that children of all ages did not understand humans from an inclusive perspective.

Why are other animals more closely associated with plants than with humans by students from this culture? It would seem two aspects of the students' culture worked together to produce this pattern of association. These are religion and language. The more potent of the two reasons is the religious belief of the students from this culture in the divinity of man. Humans are believed to be different from all living entities, and are seen as superior to them as in the study of Yorek et al. (2009). The human is the only entity with a soul which can live on after death. The spiritual world is a strong aspect of the Igbo culture's reality (Nwoye, 2011). In fact, God is believed to have created all other entities for the benefit of man. The students' choice of MU causality for humans can be explained by this religious view. God created man in his own image and likeness, which must be preserved from generation to generation; a case of biological essentialism. God does this through the actions of genes. Other animals and plants share the same status of being created as food and for the well-being of man; therefore, causality for plants and other animals is conceived in terms of vitalism. This, therefore, is a potential source of difficulty in the understanding of biological causality among the students, as well as in the understanding of other biological concepts such as the ecosystem and other ecological relationships. Ecology has been demonstrated by researchers in the Igbo culture (Adeniyi, 1985; Agbohoroma & Oyovhi, 2015; Okebukola, 1990; Okeke & Ochuba, 1986; Shehu, 2016; Wakirwa, 2013; West African Examination Council, 2006) to be one of the most difficult domains for students to learn. The findings of this study may contribute in no small measure to the understanding of the reason for this difficulty.

The second possible explanation may be the Igbo language. In the Igbo culture, the word 'man' ('*madu*') is distinct from the word 'animal' ('*anumanu*') and at no point do they converge. This is quite different from the Western world where the word can be used in two different variants, one inclusive of humans and another exclusive of humans (Leddon et al., 2012). In line with psychologists' belief that language is the precursor of concept formation, the understanding of the relationship between humans and other animals for this group of students may prove to be very challenging. According to Leddon et al., the two meanings of the word animal belong to two nested nodes in a conceptual hierarchy, and researchers have suspected this to form peculiar challenges in the development of biological concepts for children who conceive them as different. The same is true for this group of students. The speculation that the Igbo culture gives rise to a different categorisation scheme of biological entities other than the one adopted in canonical biology is entertained. This will need to be explored further and may yield robust data that can be used for the design of curricula for non-Western cultures.

Role of culture in causal reasoning

Does the urban–rural dichotomy add to our understanding of the influence of culture on causal attributions in biological phenomena? Both urban and rural students recognise commonalities in causality between the three prompt categories, in that their preferences for causal explanations were similar across four reasoning categories. The rural students, however, were more likely to give multiple causal explanations in the span of a single response and less likely to attribute causal agency to God. The argument of Ojalehto et al. (2013) can be understood further by the trends noticed in this study. These non-Western students can be equated to indigenous adults whose ecological closeness to nature is assumed to be higher than that of their Caucasian counterparts in the USA. The multiple causal responses by the rural students can be explained by their ecologically rich causal structure that allows for perspectival reasoning about a system of relationships. This is because the interaction of rural students with natural kinds was assumed to be higher than that of the urban students. Further research that will probe the levels of ecological closeness to nature of students is required to draw conclusions.

What role did culture play in the trends noticed for this student sample? It appears the construal of the rural students was mediated by their ecological closeness to nature as their preference for a predetermined category was lower than expected for this group of students. However, it was found that their responses included more non-scientific aetiological explanations than their urban counterparts' in line with the findings of Okoro (1975) and Nzewi (2001). Whereas they were less likely to use the predetermined explanations, they privileged the interaction of spirit forces in their explanations of adaptive changes in biological entities, thus supporting the claims of Chukwuezi (2008) and Nwoye (2011).

The urban students, on the other hand, were more likely to make causal attributions using the predetermined category. It appears the context of the urban students (little interaction with other animals and plants) caused them to endorse a predetermined reasoning which is widely disseminated (Chukwuezi, 2008) in the society. As argued by Evans (2001), the adoption of any belief by a population attests to its availability and cognitive appeal.

Several studies (Geerdts et al., 2015; Leddon et al., 2012; Medin et al., 2010) have demonstrated the importance of experience in the acquisition of accurate knowledge of biological ideas and there is considerable evidence that science instruction aids in the development of accurate causal relationships. It would seem that in this study, ecological closeness to nature played a major role in the students' causal attributions. However, since there was no direct exploration of the environment of the students, we may not be so categorical about this. Further studies and evidence are required in order to confirm these assumptions.

What are the instructional implications of the results of this study? The distinction made between humans and other animals and plants may cause difficulty in the students' understanding of taxonomy and relationships between organisms in the ecosystem. The privilege given to humans as a distinct group from other animals and plants, as suggested earlier, may lead to a different categorisation scheme, yet to be identified, in the conceptual structure of this group of students. It is important, therefore, that science education researchers from this culture explore this to understand the path to take in the integration of humans with other animals into the concept animal.

Misconceptions such as conceptualising humans as not part of the larger animal group, and that humans are independent of other living and non-living things may prove difficult to relinquish as indeed is the case for students from this culture.

Conclusion

The efficacy of the national curriculum in the understanding of causality among the different biological entities is doubtful because the observed pattern did not fit the predictions of no association between causal reasoning and prompt types. The organisation of the different themes in the curriculum may be implicated in addition to the other cultural reasons given in the discussion. For instance, reproduction in humans is treated in the final year along with genetics and evolution, whereas reproduction in plants is treated along with reproduction in other animals in year 2. This requires further studies for any conclusions to be drawn. The relationship between humans and other forms of life, biological predeterminism and the boundary conditions for the realms of science and religion should be explicitly addressed in biology classes. This should begin early, during the teaching of living and non-living things. The plant–animal distinctions should also be made explicit. The everyday usage of the word *animal* as distinct from *humans* should be taken into consideration in biology teaching and addressed accordingly. Finally, as rightly pointed out by Russ et al. (2008), understanding causal mechanisms should be given equal attention as experimentation, controlling variables and argumentation in biology teaching.

Disclosure statement

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Appendix 1

Content and organisation of Nigerian biology core curriculum.

	Sub-themes		
Themes	SS1	SS2	SS3
Organisation of Life	1. Recognising Living Things 2. Classification of Living Things 1 Kingdoms: Monere, Protista and Fungi, Plantae and Animalia 3. The cell 4. The Cell and its Environment 5. Some Properties and 'Functions of the Cell	Classification of Plants	
The Organisation at Work	1. Tissues and Supporting Systems 2. Nutrition in Animals	1. Digestive System 2. Transportation System 3. Respiratory System 4. Excretory System	1. Regulation of Internal Environment 2. Nervous Co-ordination 3. Sense Organs
The Organism and its Environment	1. Basic Ecological Concepts 2. Functioning Ecosystem, Autotrophy and Heterotrophy - Food Webs and Trophic Levels 3. Energy Transformation in Nature 4. Relevance of Biology to Agriculture 5. Micro-organisms around us 6. Micro-organisms in action 7. Towards better health 8. Aquatic habitat (Marine Habitat) 9. Aquatic habitat (Estuarine Habitat) 10. Aquatic habitat (Fresh Water Habitat) 11. Terrestrial Habitat (Marsh) 12. Terrestrial Habitat (Forest) 13. Terrestrial Habitat (Grassland) 14. Terrestrial Habitat (Arid Lands)	1. Nutrient Cycling in Nature 2. Ecological Management: Association, Tolerance, Adaptation, Pollution 3. Conservation of Natural Resources 4. Pests and Diseases of Crops	1. Ecology of Population 2. Balance in Nature

(*Continued*)

Continued.

Themes	Sub-themes SS1	SS2	SS3
Continuity Of Life	1. Reproduction In Unicellular Organisms And Invertebrates	1. Reproductive Systems in Vertebrates 2. Reproductive Systems in Plants 3. Pollination in Plants	1. Reproductive System and Reproduction in Humans 2. Development of New Seeds 3. Fruits 4. Reproductive Behaviours 5. Biology of Heredity (Genetics) 6. Variation and Evolution 7. Evolution

Appendix 2

Sample Items from the Questionnaire (Questions related to the cactus plant)

(1) Why does the cactus have the spines?
- (a) It needs them *(Teleological)*
- (b) It inherited them through the genes *(Mechanistic Ultimate)*
- (c) God made them to be like that *(Predetermined)*
- (d) It just wanted to have them so it developed them *(Anthropomorphic)*
- (e) They just grew out of the cactus *(Mechanistic Proximate)*
- (f) I don't know
- (g) Others (please specify other answers or any other option from the list above other than the one you ticked)

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(2) What does the cactus use the spines for?
- (a) For defence, that is, pierce peoples' hands and reduce water loss *(Teleological)*
- (b) To place it in the cactus family *(Mechanistic Ultimate)*
- (c) To be just as the creator made it *(Predetermined)*
- (d) To beautify itself as a flower *(Anthropomorphic)*
- (e) To complete the number of its body parts *(Mechanistic Proximate)*
- (f) I don't know
- (g) Others (please specify other answers or any other option(s) from the list above other than the one you ticked)

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(3) How did the cactus plant get its spines?
- (a) It grew them from the body because it needed them *(Teleological)*
- (b) They inherited them through the genes *(Mechanistic Ultimate)*
- (c) It was created to be like that *(Predetermined)*
- (d) It decided to grow them for some reasons *(Anthropomorphic)*
- (e) That is the natural thing for the cactus *(Mechanistic Proximate)*
- (f) I don't know
- (g) Others (please specify other answers or any other option(s) from the list above other than the one you ticked)

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*Note that the reasoning categories in parentheses are not included in the questionnaire given to the students. They were rather the coding by the experts.

Appendix 3

Interview Protocol Related to the Cactus

(1) How did this cactus plant get all these spines?
(2) Contingency question(s) (if any)
(3) Why did the cactus develop these spines?
(4) Contingency question(s) (if any)
(5) Would these spines be of any advantage to the cactus?
(6) How (if yes)?
(7) Contingency question(s) (if any)
(8) Did this cactus plant think about the spines before it developed them?
(9) Why do you say so (if yes)?
(10) Contingency question(s) (if any)
(11) Now look at the stem (showing the student the stem). Why is it green in colour?
(12) Contingency question(s) (if any)
(13) How did it get the green colour?
(14) Contingency question(s) (if any)
(15) Would this green colour be of any advantage to the plant?
(16) How? (If yes)
(17) Contingency question(s) (if any)
(18) Did this cactus plant think about the colour before it developed them?
(19) Why do you say so?
(20) Contingency question(s) (if any)
(21) Please tell me about other features you see in this cactus plant. How were the features formed, and why were they formed?