Some Socio-Cultural Factors Impacting Scientific Explanations by Science Students: A Nigerian Case Study

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Abstract

The goal of this study was to examine how socio-cultural factors impact Nigerian students' explanation of scientific phenomena. Additionally, it sought to find out how such factors can be harnessed for improving performance of students on tasks requiring explanations in science. The design was a case study implemented in two schools over a 9-month period involving qualitative and quantitative data-gathering techniques. The topics covered were diversity of organisms, Mendelian genetics, ecology, plant and animal physiology, and biotechnology. During the course of the study, scripts of students containing answers to questions demanding explanation of biological phenomena were graded. A random sample of students was interviewed every two weeks to seek in-depth information on why they offered the explanation to the biological phenomenon in their answers. The teachers noted the socio-cultural attributes colouring each explanation. Extensive and indepth follow-up reviews by the research team aggregated five socio-cultural attributes of the explanations namely language, habitat, religious orientation, socio-economic status and gender. The study suggests that science teachers in Africa should look beyond traditional variables in the quest to explain and bolster students' performance in science.

Introduction and Objectives

One of the four canons of science espoused by Einstein (1954; p. 105) is explanation, others are observation, measurement and prediction. Down through the ages, public understanding of how a scientist works is in being able to explain naturally-occurring phenomena. What causes "blood moon"? Why are some persons darker in colour than others? Why do bats sleep hanging upside down? These are some of the questions that are posed to scientists. The public, especially the schooling community, reposes confidence in being served correct answers to these questions (Atwater & Riley, 1993; Mutegi, 2011; Xu, Coats & Davidson, 2012; Okebukola; 2014). Scientific explanation is therefore at the heart of doing science. It is one of the early steps in building theories that model how the real world works. With growing uncertainties in recent occurrences in nature notably reduced predictability of weather systems and emergence of new forms and variants of communicable and non-communicable diseases, the pressure on scientists especially in Africa, to offer more accurate explanations, is building up by the day.

There is an emerging global consensus on the importance of explanation as reflected in the goals of science curriculum all over the world. For instance, in a review of the objectives of biology teaching in the US, UK, Canada, China, Japan, South Africa, Russia and Germany, Atkinson (2009) found a common thread in the statements relating to "students identifying problems, formulating hypotheses, experimenting and explaining their findings". In Nigeria, the science curriculum at all levels of the education system demands that students should be able to explain their observations hence school and public examinations place accent on students' answers to questions that go beyond recording of scientific data or definitions of terms to explaining observed scientific phenomena, events or processes. An emerging and worrying trend is the declining performance of students in tasks demanding scientific explanations. Whereas scores on test items on recall of facts and definitions in the Nigerian senior school certificate examination have been found to increase slightly over the years, performance on test items demanding explanation has continued to take a dip. An analysis of students' performance in the sciences in the General Certificate of Secondary Education of the UK (Williams, 2011), National Senior Certificate of South Africa (Harrison, 2010) is indicative of the non-local nature of this problem. Studies on why this is so have narrowed their gaze on school factors including the quality of delivery of science instruction. In spite of efforts to improve instruction, this problem would appear to linger indicating the existence of some latent variables that need to be explored. The exploration of socio-cultural factors was adjudged a promising direction to turn since a rich corpus of studies (see review by Okebukola, 2010) has implicated culture in students' performance in science. The goal of this study was to examine how socio-cultural factors impact on the explanations of biological phenomena given by students. Additionally, it seeks to find out how such factors can be harnessed for improving performance of students on tasks requiring explanations in biology.

Theoretical Framework

We hinged the theory base of this study on Vygosky's social constructivism which underlines that social interaction and cultural influences impact on learning, in this case, learning of science. The key elements in this framework are cognitive dialogue, proximal development, social interaction, culture and inner speech (Vygotsky, 1962). As Woolfolk (2004) noted, the issue of diversity of the class becomes important in learning science in a socio-cultural context. Diversity can be defined to include ethnic background, gender, religious affiliation cognitive preference and worldview. Conceptually, this study is on scientific explanation. A scientific explanation is a description of underlying causes or implicating effects of an observed phenomenon (Trout, 2007). Explanation as Trout (2007) further notes, has been understood in a number of ways, including being a process of unifying disparate phenomena, identifying the causal or statistical relevance of mechanisms, or a merely pragmatic virtue offering a narrative designed to account for an effect. According to Hempel (1965), such an explanation is always a deductive derivation of the occurrence of the event to be explained from a set of true propositions including at least one statement of a scientific law. (The event to be explained is called the explanandum; the set of explaining statements is sometimes called the explanans.) In other words, a deterministic event explanation is always a sound, law-involving, deductive argument with the conclusion that the explanandum event occurred.

Methods: Design, Procedure and Data Sources

The design was a case study in which we deployed qualitative and quantitative data-gathering techniques, implemented over a 12-month period. There were two participating secondary schools located in Lagos in the south-western part of Nigeria. Students enrolled in the school are from a broad spectrum of cultural backgrounds in Nigeria in terms of language, religious affiliation, socio-economic status and habitat (rural/urban location of residence). The 218 students (96 girls, 122 boys) with mean age of 15.4 years were enrolled in senior secondary biology. About 18% of the students live predominantly in rural areas. Within this group, 52% are from fishing communities in coastal areas, 41% from peasant farming communities in the hinterland while others are from villages where petty trading predominates. The bulk of the students, that is 72% grew up and live in urban centres. The socio-economic status of the families of most of the students was classified largely as middle-level. A small fraction (5%) especially those from rural communities belongs to the low socio-economic group.

Five regular biology teachers in the selected schools taught the biology lessons during the course of the study. Over a 9-month period of being participants in biology classroom transactions, the students were sufficiently relaxed to freely express themselves during the interview phase of the study. During the course of the study and via the medium of fortnightly tests, students were asked to provide explanations relating to biological concepts learned every two weeks of class instruction and laboratory work. The typical class during the period consisted of whole-class lectures and small-group discussions. The laboratory sessions were mainly teacher demonstration with occasional small-group or individual hands-on exercises when biological specimens were ample.

Every week, students had 90 minutes of biology class time. One week of classroom instruction alternated with laboratory work the other week. Class session typically begins with teacher reviewing previous lesson. This is followed by presentation of content for current lesson during which ample room is given for student participation through questions and answers. Class concludes with teacher summarising the lesson and giving out assignments. The laboratory work normally begins with teacher demonstration. This is followed by student individual or group work. The topics covered during the course of the study were cells and molecules of life, diversity of organisms, Mendelian genetics, ecology- organisms and environment, plant and animal physiology, applied ecology, and biotechnology.

Each fortnightly test had a component which required students to explain a biological phenomenon or process. Answer scripts were graded using a scoring scheme with six criteria- (1) articulation of causal claims; (2) use of appropriate and sufficient evidence to support these claims; (3) use of reasoning that draws on scientific principles to explicitly link the evidence to the claim; (4) accuracy of reasoning; (5) application of appropriate scientific principles; and (6) correct sequence of events. This scheme is a blend of the marking scheme of the West African Examinations Council for biology and the rubric proposed by McNeill, Lizotte, Krajcik, & Marx, (2006). The five biology teachers who were trained using the scoring scheme (inter-rater reliability of 0.89), graded the scripts under the supervision of the lead author. During the 9-month duration of the study, a total of 3,924 scripts containing answers to questions demanding explanation of biological phenomena were graded. The scores of the 218 students were grouped into high (upper 25%), average (middle 50%) and low (lower 25%). Every two months, a random sample of five students from each group was interviewed to seek in-depth information on why they offered the explanation to the biological phenomenon in their answers. Interview sessions took place during class free periods and lasted about 20 minutes on the average for each session. Interview data were audio recorded, transcribed and coded. The teachers noted the socio-cultural attributes colouring each explanation.

Results, Discussion and Conclusion

Follow-up reviews by the research team aggregated five socio-cultural attributes of the explanations namely language, habitat, religious orientation, socio-economic status and gender. The following is a report on the socio-cultural factors unveiled from the data collected in the study.

Language

About 43% of the explanations were influenced by the degree of fluency in the language of writing the explanation. This supports findings of previous research (Thomas and Collier, 2002) that language is a key factor in teaching and learning. Chukwu (not real name; 16-year old male) one of the target students presented a rich and detailed explanation of the question: Explain how energy flows from one trophic level to the next in an ecosystem". Chukwu wrote:

> In an ecosystem, the energy from the sun is trapped by green plants that are primary producers at the bottom of the pyramid. When green plants are eaten e.g. by a goat (primary consumer), the energy is passed to the primary consumer. Part of this energy is converted to body heat. If the primary consumer is warm-blooded, it will eat more plants because of the energy loss, but if cold-blooded like a lizard, it will eat less. Energy flows to secondary consumers e.g. a hawk when they eat primary consumers. Tertiary consumers such as man finally get the energy by eating secondary consumers. At each level, energy is lost so man gets very little at the end of the day.

Interview data confirmed that Chukwu grew up in a home where English, the language of instruction in schools, is the primary language of conversation. He narrated: "at home, my parents give us support to read English books and newspapers". Comparison of the explanations of Chukwu of energy changes in the ecosystem with about 82% of those students with rich explanation shows great similarity in their level of English language fluency. In contrast, students with greater fluency in the mother tongue than English were less explicit in their explanations. Over three quarters of these students were in the average and low score category. Risi, a 15-year old girl in this group gave the following written explanation to the question: "Explain the process of movement of mineral salts from the soil to the leaf of a flowering plant".

Risi: Mineral salts are taken by the root hairs to the plant. They move through the xylem to the leaves".

It was however a different story when Risi was asked to explain the movement of mineral salts during the interview session. Using a mixture of English and Yoruba (her mother tongue), Risi explained in detail with accompanying rough sketches, how mineral salts enter the epidermal cells of root hairs by diffusion and active transport. The minerals (often called "minaral" by Risi in line with local pronunciation) are further moved by diffusion to the xylem vessels and pulled "by a force from the top" to the leaves. Intrigued by the level of detail in Risi's oral explanation in contrast with the rather weak and sketchy written explanation, we inquired if time was a constraint in the test. Risi: "No sir. We had enough time. I cannot explain myself well in English. I don't want the teacher to punish me if I make English mistake". When we explored this strand of evidence further, we found that 93.6% of those students in the upper 25% were in the high achieving group in the English language class.

Student habitat

Student habitat defined as where the student spends most of his or her time outside school was found to play a role in the biological explanations offered by the students. This reflected significantly in ecological concepts as students regardless of their group (high, average or low) copiously coloured their explanations in ecology with their rural/urban context. The question that exemplifies this trend is: "Using examples, explain the feeding relationships in a food web". Over 90% of students from the coastal area used aquatic environment examples. Their explanation had several common elements. A typical explanation given by Senapon in the average achievement group is:

> My example is an aquatic food web. Organisms in the water such as fish, water snails, water boatman require energy for daily life. The energy is derived by eating organism in the lower food chain such as planktons. The plankton get their energy from the sun. Several food chains in the aquatic environment are linked to form the food web. The energy used throughout the web comes from the sun.

Most of the students from the savannah geographic zone gave explanations on energy relationships within the savannah. Evidence from Sandoval and Millwood (2005) points in a similar direction.

Religious orientation, socio-economic status and gender

Explanations offered by students on sex-linked characters, albinism and human diseases were found to be largely coloured by religious orientation of the students. Socio-economic status and gender did not feature as discriminatory variables in the explanations throughout the course of the study. This is a refreshing finding since these two variables have been implicated in students' performance in science (Morrison, 2006).

Conclusions and Significance

This study examined how socio-cultural factors impact on students' explanation of biological phenomena. Additionally, it sought to find out how such factors can be harnessed for improving performance of students on tasks requiring explanations in biology. The study suggests that science teachers should look beyond traditional variables in the quest to explain students' performance. It uncovered some socio-cultural variables to which hitherto attention is weakly paid in explaining students' performance in science. It draws pedagogical attention to these socio-cultural variables as areas which science teachers should focus while delivering science instruction. Although the present study is on biological concepts, the wider reach of its findings to other areas of science can be hypothesized. Though not generalizable on account of sample-size limitation, the study offers valuable insight into how science teachers in Africa can bolster students' achievement in science by recognising the interplay of the socio-cultural variables identified in this study in the teaching and learning of science. A fuller understanding of the socio-cultural factors that enhance students' ability to make scientific explanations will be an important addition to the theory and practice of teaching and learning science by African students.

References

Atwater, M. M., & Riley, J., P. (1993). Multicultural science education: Perspectives, definitions, and research agenda. *Science Education, 77*, 661-668.

Einstein, A. (1954). *Ideas and Opinions*, New York: Random House.

Harrison, O. (2010). The national school certificate in the sciences. *Journal of Science Education,* 22(1), 11-23.

Hempel, C. (1965). *Aspects of Scientific Explanation*. Free Press, New York.

McNeill, K. L., Lizotte, D. J, Krajcik, J., & Marx, R. W. (2006). Supporting students' construction of scientific explanations by fading scaffolds in instructional materials. *The Journal of the Learning Sciences,* 15(2), 153 - 191.

Morison, S.T. (2006). *Factors in students' achievement in science*. New Delhi: ABT Press

Mutegi, J. W. (2011). The inadequacies of "science for all" and the necessity and nature of a socially transformative curriculum approach for African American science education. *Journal of Research in Science Teaching, 48*, 301-316.

Okebukola P.A.O. (2010). *Review of studies on culture and science learning*. Lagos: OSF Press.

Okebukola, P.A.O. (2014, April). Advances in science and technology and national security. Keynote address presented at the 49th Annual Conference of the Science Association of Nigeria, Ilorin.

Okebukola, P. A., Owolabi, O. & Okebukola, F. O. (2013), Mother tongue as default language of instruction in lower primary science classes: Tension between policy prescription and practice in Nigeria. *Journal of Research in Science Teaching*, 50 (1), 62–81.

Sandoval, W.A. and Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. Cognition and Instruction, *23*(1), 23-55.

Strevens, M. (2004). The causal and unification accounts of explanation unified – causally. Noûs 38:154–176.

Trout, J.D. (2007). The psychology of scientific explanation. *Philosophy Compass* 2/3 (2007): 564–591

Vygotsky, L.S. (1962). *Thought and language*. Cambridge, MA: MIT Press (original work published in 1934).

Williams, M.S. (2011). Analysing performance in the sciences in GCSE. *Journal of Science Education,* 23 (2), 124-138.

Woodward, J. (2003). *Making things happen: A theory of causal explanation*. Oxford University Press, Oxford

Woolfolk, A. (2004). Educational psychology. Boston, MA: Pearson Allyn & Bacon.

Xu, J., Coats, L. T., & Davidson, M. L. (2012). Promoting student interest in science: The perspectives of exemplary African American teachers. *American Educational Research Journal, 49*(1), 124-154.