Secondary School Biology Teachers' Perceptions of the Nature of Science

Grace C. W. Ndeke

Fred N. Keraro

Curriculum, Instruction and Educational ManagementDept,
Egerton University
P.O. Box 536-20115, Egerton, Njoro, Kenya

Abstract

The purpose of this study was to investigate secondary school biology teachers' perceptions of the Nature of Science. Cross-section survey research design was employed. The population of the study comprised of all biology teachers in public secondary schools in Kericho and Kajiado counties in Kenya. The total population of biology teachers was 347 from which a sample of 205 was selected using proportionate random sampling technique. A biology teachers' questionnaire was used to collect data. Descriptive statistics was used to analyze the data. The findings reveal that a high percentage of teachers do not have informed views of the Nature of Science (NOS). The findings provide valuable information to the teacher trainers and policy makers that majority of teachers' perceptions reflect their inaccurate conceptualization of the NOS and that is likely to influence their classroom practices. It is recommended that elements of the philosophy of science and more specifically NOS beintegratein their teacher education courses. This would enable teachers to have a better understanding of NOS and positively influence their classroom practices and enhance the learning of science subjects at the secondary school level.

Keywords: Biology, biology teachers, perceptions, Nature of Science.

1.Introduction

Science Educators and major science education organizations are increasingly advocating for the preparation of a scientifically literate citizenry (AAAS, 1993; National Research Council, 1996). According to Abd-el-Khalick, Bell, and Lederman (1998), scientific literacy refers to one's understanding of the concepts, principles, theories, and processes of science and the awareness of the complex relationships between science, technology, and society. Holbrook and Rannikmae (2009) define scientific literacy as developing ability to creatively utilize appropriate evidence based scientific knowledge and skills in everyday life or in a career to solve problems and make decisions. According to the Organization for Economic Cooperation and Development [OECD], (2013) a scientifically literate person should be able to explain phenomena scientifically, evaluate and design scientific inquiry and interpret data and evidence scientifically. OECD further elaborates on scientific literacy as the ability to engage with science related issues and with ideas of science as a reflective person. According to Milner, Sonderyeld and Rop (2014), scientific literacy can be achieved if real science can be taught in schools with students gaining practical understanding of the Nature of Science (NOS).

Nature of Science refers to the epistemology of science or the values and beliefs inherent in the development of scientific knowledge, which involves human imagination and creativity (Lederman, 1992; Lederman, Abd-El-Khalick, Bell and Schwartz (2002)). According to American Association for the Advancement of Science, (1993, & 1998), Smith, and Scharmann (1999), components of the nature of science (NOS) are essential and a central element of the school science curriculum. Scientific knowledge also involves imagination and creativity, a combination of observation and inferences and is socially and culturally embedded. Osborne, Bartholomew, and Ratcliff (2003) have identified these aspects of science to include; methods of science, nature of scientific knowledge, processes and practices of a scientific community, applications and implications of scientific knowledge.

Lederman (1992) and Lederman, et al. (2002) suggest that philosophers, historians, and sociologists of science have a consensus regarding certain aspects of the nature of science, which include: all scientific knowledge is subject to change (tentative) in light of new evidence and that it relies heavily on empirical evidence; Scientific knowledge is derived from a combination of observation and inference and that scientists use creativity and imagination throughout their investigations.

Another key aspect of the NOS is that no single universal scientific method is used during investigations; instead, scientists employ a wide variety of approaches to generate scientific knowledge. On theories and laws Lederman et al indicate that the two constitute two distinct types of knowledge. On subjectivity and objectivity of the scientific enterprise, they indicate that subjectivity is part of the scientific enterprise since a scientist's intuition, personal beliefs and societal values play a role in the development of scientific knowledge. However scientists apply self-checking mechanism like peer review to improve on the objectivity of scientific knowledge.

In the teaching and learning of science, the understanding of the NOS is considered a significant aspect of scientific literacy (Lederman, 1999). It is, therefore, important for a science teacher and learners to understand the NOS. This is because prospective and practicing secondary school science teachers' knowledge and beliefs about the philosophy of science is that science is perceived as an established body of knowledge and techniques, which requires minimal justification (Gallagher, 1991). This makes the science teachers not to realize the tentativeness of scientific knowledge or its social dimensions. According to Niiniluoto (2011), science does not grow by accumulating new established truths upon old ones. Science develops by having conflicting theories about how everything works in the natural world. Through experimentation, one of the theories becomes dominant and is accepted by the scientific community (Bird, 2011). Scientists piece together bits of information by rigorously testing it through experimentation.

According to NRC (1996), science instruction should go beyond teaching science as a body of knowledge. Instead, teachers should engage learners in a broader view of science that addresses the development of scientific knowledge and the very nature of the knowledge itself. Tsai (2006) argues that one of the major goals of science education is to help learners develop an understanding about the nature of science. This enables learners develop an accurate view of what science is including the type of questions science can answer, how science differs from other disciplines and the strength and limitations of scientific knowledge. Wong and Hudson (2008) argue that teaching the NOS can attract more young people to science especially if it conveys a sense of excitement through its emphasis on creativity and other intellectual endeavors. Teachers who do not understand the nature of science (NOS) are likely to transmit misconceptions to their students (Lederman et.al, 2002). This study, therefore, sought to find out biology teachers perceptions on the nature of science.Lederman (1999) carried out a study in United States of America using high school biology teachers to investigate the relationship of the teachers understanding of the nature of science and their classroom practices. He found that teachers' conception of science do not necessarily influence their classroom practices. Teachers' intentions, goals, and perceptions of students are the factors that influence a teacher's instructional strategy. He also states that teachers believed that only a certain type of scientific knowledge is tentative and that creativity, imagination, and subjectivity had a limited place if any in the development of scientific knowledge. He, therefore, concludes that unless a teacher clearly intends to address the nature of science and follows through with explicit emphasis during instructions, students would not develop a clear understanding of the nature of science that happens to be consistent with the organization of a particular lesson or activity.

A study carried out by Krupp and Webb (2003) in Eastern Cape Province of the republic of South Africa had a sample of 136 practicing science teachers. The study investigated teachers' view of the nature of science. They also investigated how their views influenced their classroom practices. They found that the classroom practices of science teachers were largely based on transfer of textbook knowledge from a teacher to learners with emphasis on scientific principles and laws. This gives the impression that science is a collection of irrefutable facts that have tobe learned. They also found that the role of imagination and creativity in the development of scientific knowledge seemed to be a difficult construct for teachers. For most of them, the scientific enterprise is mostly based on logical reasoning and experimentation without any creative aspects of the process. Hence, this study sought to find out biology teachers' perceptions of the nature of Science.

Objective of the study

The main objective of the study was to explore secondary school biology teachers' perceptions of the Nature of Science.

2.Methodology

2.1 Research design

The study employed descriptive cross sectional survey research design. Through descriptive research, one obtains pertinent information concerning the status of a phenomenon and draw valid conclusions (Koul, 1993; Kothari, 2003). The cross sectional survey design was found to be appropriate because a lot of information is collected in a relatively short time (Gall, Gall & Borg, 2003).The design involves collection of data at one point in time from a random sample that represents a given population at a particular time (Wiersma&Jurs, 2005).

The design was appropriate for the current study since information was gathered at one point in time on the status of biology teachers concerning their perceptions of the nature of science.

2.2 Sampling procedures and sample size

The study focused on biology teachers' in public County secondary schools. A sample of 205 teachers was selected using proportionate random sampling technique (Kothari, 2003). Each County contributed a sub sample proportionate to its population. Thus, Kericho County with a population of 216 biology teachers contributed 128 teachers to the sample, while Kajiado County with a population of 131 biology teachers contributed 77 teachers. Lists of all biology teachers in each County were drawn and used as sampling frames. Biology teachers in each County formed a stratum. Each stratum then contributed to the sample a number that was proportionate to its size of the population. Simple random sampling technique was used to select biology teachers that participated in the study.

2.3 Instrumentation

The Biology Teachers' Questionnaire (BTQ) was used to collect data on teachers' perceptions of the NOS. The items were adapted from Kurup and Webb (2003). BTQ had 11 Likert scale type items. The items had a scale of zero (0) to four (4). For the positive statements, a score of four showed that a teacher strongly agreed with the statement while a score of 0 indicate that a teacher strongly disagreed with the statement. For the negative statements, a score of 4 indicated that a teacher strongly disagreed with the statement while a score of 0 indicated that a teacher strongly agreed with the statement. This gave a minimum score of 0 and a maximum score of 44. Five experts in science education validated the research instrument. The focus of validation was on content validity. The research instrument was pilot tested using 30 biology teachers in Nakuru County that has similar characteristics as Kericho and Kajiado counties. The results of the pre-test were used to estimate reliability of the instrument. The reliability of BTQ was estimated using Cronbach's alpha coefficient. The reliability coefficient of 0.817 was obtained. This was above the accepted threshold for social science research. Cronbach's coefficient alpha is appropriate because the items in BTQ were Likert type and had a range of scores.

Upon receiving the research permit from the National Commission for Science, Technology and Innovation, the researchers visited the Education Offices in Kajiado and Kericho respectively to notify them of the intention to collect data from teachers in schools in their areas of jurisdiction. The researchers visited the sampled biology teachers in their respective schools through the respective principals and informed them of the purpose of the study. The researchers self-administered the questionnaire to the sampled biology teachers to ensure higher return rate. The study generated qualitative data. Descriptive statistics was thus used for analysis. Theresponses from Likert type items in the BTQ instrument were coded to obtain the magnitude of what to be measured. The coded responses were analyzed with the help the Statistical Package for Social Science (SPSS) version 20. Total score from each item in the questionnaire was generated. The total score was then used to generate the mean out of a maximum of 4.

Results

The study sought to find out secondary school biology teachers' perceptions of the nature of science. Biology teachers' questionnaire was used. The expected responses in this section were for teachers to indicate the degree to which they agreed with the provided statements that describe the nature of science. The responses ranged from strongly agree, agree, no opinion, disagree to strongly disagree.

The scores ranged from 0 for strongly disagree to 4 for strongly agree if the statement was positive. For negative statements 0 was for strongly agree and 4 for strongly disagree. A summary of their responses in terms of means and standard deviation is presented in Table 1.

Table 1 Mean and SD of Teachers' Perceptions of the Nature of Science

Indicate the option that best describes your view on the statement N=205	**Mean**	**SD**
The development of scientific knowledge is an orderly rational and step by step process (scientists first collect data and then generate theories by looking for the patterns in the data)	.50	.77
Scientists perform experiments/investigations when trying to solve problems by using their imagination and creativity only during planning and design of these experimental investigations.	1.38	1.15
The theories developed by scientists are influenced by the social political and cultural contexts (situations) prevailing at the time.	2.40	1.30
After repeated and successful experimental verification a scientific theory becomes a law	0.72	.90
Scientific theories may change with time	2.96	1.07
The “scientific method” is the only way to study nature and natural phenomenon.	1.99	1.21
Indigenous knowledge (knowledge held by different cultures) cannot be regarded as scientific knowledge.	1.96	1.25
Two independent scientists make the same conclusion from an observation of a natural phenomenon (draw the same conclusion after observing a forest fire)	2.00	1.22
Scientific theories reveal the absolute truth [there is no uncertainty about the truth]	2.24	1.18
Science should be thought of as being separate from technology	1.58	1.29
Observations made by a scientist can be objective but the conclusion drawn from the observation can be subjective	2.72	1.00
Overall	1.85	.40

The results indicate that biology teachers had limited understanding of the nature of science with an overall mean of 1.85 out of a maximum of 4 which is below the average of two. The items on “after repeated and successful experiment verification a scientific theory becomes law” and “the development of scientific knowledge is an orderly rational and step by step process (scientists first collect data and then generate theories by looking for the patterns in the data)” had the lowest mean of 0.72 and 0.50 respectively. This means that biology teachers have misconceptions that theories and laws are the same kind. It also indicates that most biology teachers believed scientific knowledge is developed through a systematic process. This item was followed closely by the statement “scientists perform experiments when trying to solve problems by using their imagination and creativity only during planning and design of experimental investigations”, with a mean of 1.38. This shows that biology teachers had limited understanding of the role of imagination and creativity in the whole process of investigation not just during planning and design of investigations. The statement that “Scientific theories may change with time” had the highest mean of 2.96 out of the possible 4. This indicates that most biology teachers had an understanding that theories may change with time when new discoveries are made.

3. Discussion of the Results

The results indicate that secondary school biology teachers’ understanding of the nature of science is inconsistent with the contemporary interpretation, with an average mean of 1.86 out of a maximum four. These findings are in agreement with other studies by Akerson, Abd-El-Khalik and Lederman (2000); Lederman (1992); Kurup and Webb (2003); Lederman et al. (2002). These researchers concluded that generally teachers have naive views on various targets of the NOS. According to Lederman et.al the main aspects of the NOS include, science is empirical based and scientific knowledge is tentative or subject to change. Scientific knowledge is theory laden since scientist’s beliefs, prior knowledge, training and experience influence their work. Creativity and subjectivity are also inherent in scientific knowledge and there is no single scientific method or sequence used by scientist to develop infallible knowledge. Science is a human enterprise hence is social-culturally influenced. On theories and laws, Lederman et al. argue that the two are different and have different functions in development of scientific knowledge and hence theories cannot become laws.The results also indicate that the majority of biology teachers believed that scientific theories become law (M=0.72).

This is consistent with findings by Abd-El-Khalick and Boujaude (1997), Lederman (1992), Kurup and Webb (2003) and Abd-El-Khalik et.al (1998). In their findings, teachers could not differentiate between a theory and a law. Most teachers believed in a hierarchical relationship between theories and laws, where theories develop to become laws, which are absolute and not subject to change. According to Akerson, Abd-El-Khalick and Lederman (2000), theories and laws are different kinds of scientific knowledge and serve different functions. Theories are inferred explanations for observed phenomenon and serve to explain large sets of seemingly unrelated observations in more than one field of investigations. They have a role in generating research problems and guiding further investigations.

This makes theories not to be directly tested since they are based on a set of assumptions (Lederman et al., 2002), and can only use indirect evidence to support them and establish their validity. Scientific laws are descriptive statements of relationship among observed phenomena and mainly state, identify or describe relationships among phenomenon (Akerson et al.; Lederman et al., 2002).

On the use of imagination and creativity by scientists, most teachers believed that imagination and creativity are only used by scientist during planning and design of investigations (M=1.38). According to study by Akerson et al. (2000), most of the participants indicated that scientists use creativity in their work but only when coming up with good experimental designs or problem solving. They argued that most of the participants in the study failed to recognize the use of imagination and creativity throughout the scientific investigations especially when interpreting the data. Kurup and Webb (2003), in their study found that most teachers had difficulty in understanding the role of imagination and creativity in development of scientific knowledge. This is due to their belief that the scientific enterprise is mostly based on reasoning and experimentation without any creative aspect in the process.

There is, therefore, a need for teachers to realize that imagination and creativity are important at all stages of investigations including planning, designing, data collection and interpretation (Wong &Hodson, 2008). This in turn would enable learners to appreciate science as an activity that involves creativity and imagination as much as many other human activities (Osborne, Bartholomew &Ratcliffe, 2004)The results further indicate that about 50% of biology teachers believed that using "the scientific method" is the only way to study nature (M=2.0390). This is consistent with the findings of Akerson et al. (2000), Abd-El-Khalick et al (1998), Kurup and Webb (2003). In their findings, the participants believed in universal stepwise procedure "the scientific method" for doing science, therefore dismissing the creative and imaginative nature of the scientific process. Lederman et al. (2002), argue that scientist observe, compare, measure, test with no single sequence of activities that can lead to valid solutions or answers.According to Milner, Sonderyeld and Rop (2014), real science should be taught in schools with students gaining practical understanding of the NOS in order for them to achieve scientific literacy. Being scientifically literate allows one to have a greater understanding of issues one encounters on a daily basis (Hazen, 2002). This can only be achieved if science educators continue to develop and assess the effectiveness of various instructional approaches which are aimed at promoting the true nature of science in the context of science education courses (Akerson et al., 2000).

4.Conclusion and Recommendation

Secondary school biology teachers had inadequate understanding of nature of science. Most teachers believed that scientific theories become laws and the use of imagination and creativity by scientist only occurs during planning and design of investigations. This indicates that most biology teachers have misconceptions on how scientist work and how scientific knowledge is developed. This in turn limits teachers in enhancing learners' scientific skills and attitudes. This would also limit biology teachers' capacity to prepare and provide learning activities/experiences that would promote meaningful learning. In view of the findings of this study it is recommended that teacher training institutions emphasize the nature of science in science education programmes. This would sensitize teachers on the how scientific knowledge is developed and also learn the practices and attitudes of scientist in order to inculcate the same in their learners who are the future scientist.

References

Abd-el-Khalick, F., Bell, R.L, Lederman, N.G. (1998). The nature of science and instructional practice: making the unnatural natural. *Science Education,* 82, 417-436.

Abd-El-Khalick, F. &Boujaude, S. (1997). An exploratory study of the knowledge base for teaching science. *Journal of Research in Science Teaching, 34, 673-699.*

Akerson, V. L., Abd-El-Khalick, F. & Lederman, N. G. (2000). Influence of a Reflective Explicit Activity Based Approach on Elementary Teacher Conceptions of Nature of Science. *Journal of Research in Science Teaching,* 37(4), 295-317

America Association for the Advancement of Science (1993). *Benchmark for Literacy.* New York. Oxford University Press.

American Association for the Advancement of Science (1998) *Blueprint for reform;Science Math Technology Education.* New York Oxford University Press.

Bird, A. (2011). "Thomas Kuhn". In Edward N. Zalta (ed.), *The Stanford Encyclopedia of Philosophy (winter 2011 Edition),*. Retrieved July 31, 2011, from http://plato.stanford.edu/archives/win2011/entries/thomas-kuhn/

Gall, M.D., Gall, J.P. & Borg, W.R (2003). *Educational Research: An introduction (7th Edition)* Pearson Education Inc.

Gallagher, J.J. (1991). Perspective & practicing primary schools Science teachers Knowledge and beliefs about the Philosophy of science. *Science Education, 75(1) 121-133*

Hazen, R. M. (2002). *Why should you be scientifically literate? American institute of biological science*. Retrieved from http://www.actionbioscience.org/newsfountiers/hazen.html#primer

Holbrook, J. &Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education, Vol. 4, no. 3, 275-288.*

Kothari, C.R. (2003). *Research Methodology: Methods and Technique. (2nd Ed)*. WishwaPrakashan, India.

Koul, L.K (1993). *Methodology of Educational Research.* Vikas publishing Hsepvt ltd.

Kurup, R. & Webb, P. (2003). *Does the Classroom Practice of Science Teachers Reflect Their Conceptions Regarding the Nature of Science?* Retrieved July 13, 2011, from www.episteme4- hbsce.tifr.res.in/proceeding/edu/ku

Lederman, N.G. (1992). Students and teachers conception of the nature of science. A review of the research. *Journal of Research on Science Teaching, 29, 331-359.*

Lederman, N.G. (1999). Teachers understanding of the nature of science and classroom practice. Factors that facilitate or impede the relationship *Journal of Research in ScienceTeaching*, Vol 36 (8)916-929).

Lederman, N. G., Abd-el-Khalick, F., Bell, R. L. T, & Schwartz, R. S. (2002). Views of the nature of science questionnaires. Towards valid and meaningful assessment of learners conception of the nature of science. *Journal of Research in Science Teaching, 39(6) 497-521.*

Milner, A. R., Sonderyeld, T. A. &Rop. C. R. (2014). The influence of an intensive and integrated place based professional development program on teachers' views of nature of science. *Current Issues in Education, vol. 17(1).*

National Research Council (1996). *National Science Education* Standards Washington DC National Academic press.

Niiniluoto, IIkka, "Scientific Progress", *The Stanford Encyclopidia of Philosophy (summer 2011 Edition),* Edward N. Zalta(ed). Retrieved July 31, 2011, from URL=<http:plato.stanford/archives/sum 2011/entries/scientific progress/>

OECD (2013). *PISA 2015 Draft Science Framework.* Retrieved January 22, 2015, from www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20science%2

Osborne, J., Bartholomew, H. & Ratcliff, M; (2003). T*eaching Students Ideas about Science: Five Dimensions of Effective Practice.*Doi 10.1002/Sce 10136. Retrieved June 15, 2011, from *www.interscience.wiley.com.*

Smith, M. &Scharmann, L.C. (1999). Defining versus describing the nature of science. A pragmatic analysis for classroom teachers and science educators. *Science Education, 83, 493-509*

Tsai, C. (2006). Reinterpreting and reconstructing science: Teachers' view changes towards the nature of science education. *Teaching and Teacher Education, vol. 22, pp 363-375.*

Wiersma, W. &Jurs, S. G. (2005). *Research Methods in Education. An introduction* (8thEd.). Pearson Education Inc.

Wong, S. L. &Hodson, D. (2008). "From the horse's mouth: What scientists say about scientific investigations and scientific knowledge." *Science Studies and Science Education, 109-130. DOI 10.1002/sce.20290.*