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Contents

History of Biology to Enhance the Understanding of Nature of Science

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Abstract

Science is a self correcting process and it produces reliable and objective knowledge to fulfil the needs of the society. And Nature of science is a very important part of the Science teaching and learning. In this article history of biology is taken as a tool to teach in classroom to enhance the understanding of Nature of Science of students. This is very well known approach but people are not using it in their teaching learning process. Here some examples are included to show their relationship with different aspects of Nature of Science. Engagement of the whole class in an efficient way can be done through many ways among them one of the very effective way is using the history of a discipline in their teaching learning process. And in this article many examples are given for the teachers to use in the classroom. One can use different other examples to enhance the understanding of Nature of Science among the students.

Key words: *NOS, Understanding of science, History of Biology.*

Introduction

Science is always known as the process of understanding and exploring our own surrounding. Human beings are always very curious about the pattern and existence of the natural world. So the way we understand and learn about our universe is a constantly evolving area. For the sake of this new concepts are regularly coming out and Nature of Science (NOS) is the well known way to know and understand science and its processes. To find a single definition of NOS is always a topic of contradiction. In spite of this contradiction many people will agree that NOS is the area of study in which students learn how science function, how knowledge is generated and tested and how scientist perform what they do. McComas and Kampourakis(2015).

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McComas, Clough and Almazroa (1998) suggested that: -

The nature of Science is a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive science such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavours. They explained the intersection of the various social studies of science is where the richest view of science is revealed for those who have but a single opportunity (as in the case in school settings) to take in the scenery.

We are entering into an era were world will be more dependent on science and technology than the past and present. To serve such society the citizens need to use the same skill that scientist use in their work like close observation, careful reasoning and creative thinking. The capacity of an individual to use scientific knowledge and the way of thinking depends on the type of education he/she receive from nursery to higher education. So, it's a great demand to enhance the quality of education in the science education. To improve the quality at all the levels of education in India government has started many programes like Sarva Shiksha Abhiyan (Elementary), Rashtriya Madhyamik Shiksha Abhiyan (Secondary) and the recent is Rashtriya Uchatar Shiksha Abhiyan (Higher education).

Different types of approaches like Constructivism and evaluation system Continuous and Comprehensive Education (CCE) became the part of our education system in school. These developments of scientific literacy are also very important for a nation. Scientific literacy is defined as: the knowledge and understanding of scientific, concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.

Philosophy, psychology, sociology and history of science contributed a lot in the enrichment of NOS. In our literature, science is known as the body of knowledge, a method and a way of knowing or the values and beliefs inherent to scientific knowledge and its development. To have a single definition of NOS that every researcher can accept is difficult. There are some disagreement regarding NOS among the philosophers, scientist, historians and sociologist. However at a certain point of generality there is a shared wisdom among researchers (Smith, Lederman, Bell, McComas & Clough, 1997). They mentioned some aspects of NOS as (1) The empirical nature of scientific knowledge (2) The tentative nature of scientific knowledge (3) Creative nature of scientific knowledge (4) The social and cultural embeddedness of scientific knowledge (5) Observation, Inference and theoretical entities in science (6) Scientific theories and laws (7) The theory laden nature of scientific knowledge (8) Myth of scientific method (Leaderman, Abd-El-Khalick, Bell & Schwatz, 2002).

Using History of Science to teach about the Nature of Science

After identifying different aspects of NOS it's very important for the stalk holders of education to communicate and engage the learner in the teaching learning process of the NOS. But the fact is that one cannot teach with a single approachall the aspects of NOS. And many NOS aspects are complex enough that it is not possible to teach all the aspects in the same class to every learner. So, to teach the different aspects of NOS it is easy to give opportunity to students to learn NOS while exploring required to teach it in the context of the traditional science content. Thisapproach is an old method but it is rarely used in secondary schools.Smith & Fitzgerald, (2013) explored in his study that historical short stories as a classroom instruction is very effective. Literature has numerous studies which show that the teaching through the history of science has a positive result on school students understanding of NOS (Matthews, 1994; Abd-El-Khalick, 1998; Irwin, 2000; Stinner, McMillan, Metz, jilek & Klassen, 2003; Clough & Olson, 2004; McComas & Kampourakis, 2015).

Other studies showed that understanding of NOS in school level help students to comprehend both NOS and course content of science better (Akerson, Buck, Donnelly, Nargund, Joshi & Weiland, 2011). But the present scenario is different mostly the science books contain history only as a short note of the birth date and death date. Because of that such approach lost its essence to be an efficient way of exploring content. As per the studies of Bell, Lederman & Abd-EL-Khalick, 1997 and Khishfe & Abd-EL-Khalick, 2002 that most effective way to communicate many concepts of science is the history of science.

McComas and Kampourakis(2015) illustrated some examples from different disciplines related to different aspects of NOS. They suggested incorporating these examples into classrooms in a variety of ways as per the relevance of the content of classroom syllabus. There is no strict order of teaching these key NOS aspects. It can be used in group focusing on the overall aspects of NOS.

Some of the examples given by McComas and Kampourakis(2015) related with biology discipline:-

Historical Examples and their Relation with General NOS a Aspects		
Sl. No.	**General NOS aspects**	**Biology**
1	Science relies on empirical evidence	The experimental evidence produced by morgan and his group on the mechanisms of heredity and mutations.
2	There is no single scientific method	Watson and Crick's double-helix model for the structure of DNA, which relied on data accumulated by others.
3	Laws and Theories are distinct kinds of scientific knowledge	Mendel's laws and the missing theory of heredity at the time
4	Science is a creative process	Darwin, natural selection, and the analogy from artificial selection

(*Contd...*)

5	Science has a subjective component	Pasteur, a devout catholic, conducting experiments to show that spontaneous generation is impossible
6	There are historical, cultural, political, and social influence on science	Darwin not publishing after the reaction to the vestiges, then proceeding to publication in order not to lose priority to Wallace
7	Science and technology influence each other	The development of the cell theory by Schleiden and Schwann following the improvement of microscopes
8	Scientific knowledge is tentative	Cuvier's conclusion that questioned Lamarck's evolutionary ideas eventually came to support evolution
9	Science cannot answer all questions	Owen suggesting the existence of a divine plan in nature

1. Science Relies on Empirical Evidence

Scientists need data to justify logically any incidents or phenomena of nature. These data support or reject the hypothesis or any theory. Other methods like experiments observation, analysis, etc are also very important. A scientist can use any method either single or in group to support any observed phenomena. The common aspect is having an empirical evidence to justify any theory or to give scope for future work.

McComas and Kampourakis(2015) explained an example in biology:- Experimental evidence was important for the emergence of classical genetics during 1910-1915, through the research by Thomas Hunt Morgan and his group, who linked "Mendel's laws" to chromosomes. Morgan's group conducted experiments with Drosophila (fruit fly) and showed that genes could be envisioned as sections of chromosomes that were related to characters in the organism. They explained it as a careful breeding program and statistical analyses of the experimental results that showed genes could be envisioned as sections of chromosomes that were related to characters in the organisms. Another careful breeding program and statistical analyses of the experimental results showed that changes in particular genes could account for changes in particular phenotypes in *Drosophila*. The Morgan team's further research established that each chromosome carried a collection of genes. They also studied the production of new genetic characters by mutations and showed that these could be caused by external factors such as radiation.

More importantly, they showed that not all mutations were harmful and that they could be a source of new variation, which is necessary for the evolution of a population by natural selection (Bowler & Morus 2005; Fara, 2009) in this case, experimental evidence was crucial for the emergence of a whole new research field.

2. There is no Single Scientific Method

While doing researches in science there is some common steps which are followed by many scientists like forming and testing hypothesis, making conclusion, reporting, etc. McComas and Kampourakis(2015) explained it by giving example of James Watson and Francis Crick, they proposed the double-helical model of DNA, without doing a single

experiment themselves. Instead they interpreted, appropriately, the experimental evidence accumulated by other researchers. While Erwin Chargaff had earlier shown that any DNA molecule contained equal proportions of adenine and thymine, as well as of guanine and cytosine. Again the John Griffith had pointed out that adenine and thymine, as well as guanine and cytosine, could fit together, linking up through hydrogen bonds. Maurice, Wilkins and Rosalind Franklin had performed X-Ray diffraction studies of DNA, suggesting a spiral arrangement of the molecule. In many ways, the photographs taken by Fraklin were the key piece of evidence that Watson and crick combined with the earlier findings to come up with the model of the double-helix structure of DNA. They built actual models of the molecule, having been inspired by Linus Pauling's model-building of molecules. They were lucky and insightful, and eventually they came up with an appropriate model, although it took several years and many other scientists to work out all the details (Bowler & Morus, 2005; Fara, 2009). Overall Watson and crick proposed the model of the double helix for the structure of DNA by relying on evidence accumulated by other researchers.

3. Laws and Theories are Distinct Kinds of Scientific Knowledge

Many people have misconception that theory becomes law with the advancement of facts and experiments. They represent a ladder kind of arrangement between theories and Laws. But in reality they both are different in terms of their type'si.e Laws are the generalizations or statement of the natural phenomena, on the other hand theories are the explanations for the natural phenomena (McComas, 2004).McComas and Kampourakis(2015) gave an example to clear this misconception as Mendel's laws known as "Law of segregation" and the "law of independent assortment". But Mendel never gave any theory related with these laws to explain his observations (Bowler & Morus, 2005; Fara, 2009).

4. Science is a Creative Process

As described in NCF, (2005) appreciation of beauty and art forms is already an integral part of any human being's life, through education they must get the knowledge and understanding of the appreciation of the creativity and imagination also known as aesthetic appreciation. Every scientist applies creativity to ask/frame a question, to investigate any phenomena, to get inspiration, to imagine and investigate any evidence, etc. This is also a very crucial part of all the scientific processes. McComas and Kampourakis (2015) gave an example of the theory of natural selection given by Charles Darwin, one crucial argument of this theory comes from an analogy between natural and artificial selection. As considering the case of production of artificial varieties like the fancy colour in pigeons was a case in which the characteristics in animals were observed to change selectively from one generation to another. This helped Darwin realize that the individual variation existing in animal populations could be used as raw material

by animals who created new varieties using artificial selection. After this Darwin thought something similar might be take place in nature as well and like artificial selection, natural selection decides the survival of the fittest (Bowler & Morus, 2005; Dear, 2006). Analogical thinking is a highly creative act and Darwin perceived this analogy between artificial selection and artificial selection.

5. Science has a Subjective Component

Science has a subjective component. If two scientists observe same data they interpret it differently because of their prior experiences and expectations. As explained by McComas and Kampourakis(2015) the example of spontaneous generation can well explain this component of subjectivity. As the main idea of spontaneous generation is life could emerge from inanimate matter. And this was well accepted in the 18th century Georges-Louis Leclerc Comte de Buffon accepted spontaneous generation. Later Louis Pasteur showed that in all circumstances when the experimental apparatus was properly sterilized and contamination from the environment was prevented, no organisms appeared. And again after some time people accepted both facts because boiling kills most microorganisms but few can survive by making spores (Bowler & Morus, 2005; Fara, 2009).

6. There are Historical, Cultural, Political, and Social Influence on Science

Science cannot separate itself from the influence of the historical, political, and social influence. As science is also a process of knowing the natural phenomena that lies within the society. This can be well understood by seeing the example given by McComas and Kampourakis(2015) about the Charles Darwin's hesitation to publish his work in 1839, but he published his ideas because Robert Chamber's book "Vestiges of the Natural History of Creation" caused an enormous public reaction and a letter in june 1858 by Alfred Russel Wallace about the mechanism of evolution looked similar to Darwin's work (Bowler & Morus, 2005; Fara, 2009).

7. Science and Technology Influence each Other

Science and technology is tightly intertwined with each other as with the advancement of science technology improves. As well as the advancement of the technology also contributes the advancement of the science. as we see the example described by McComas and Kampourakis(2015) about the cell – Robert Hooke coined the word "Cell" in 1665 and he was known as one of the microscopists also, after few years in the 19th century when improvised microscope came it gave more scope for fine analysis of the cell structure and function and in 1838 the cell theory was established by Matthias Jakob Schleiden for plants and a year later by Theodor Schwann to animals. In 1858, Rudolph Virchow provided the final element to cell theory to the cell theory - the basic unit of life (Bowler & Morus,

2005; Fara, 2009). It's very clear from this example that detailed study of the cell was highly dependent on the advancement of the microscope.

8. Scientific Knowledge is Tentative

Scientific knowledge is tentative in nature. Every fact and knowledge depends on the logical and careful observation of the natural phenomena and events. In the light of new advancement of science and technology every fact and concept is prone to change and it's very natural to change ideas. For this we can consider the example given by McComas and Kampourakis(2015) about the Jean Lamarck who gave first theory of evolution in 1809. He believed that organisms were always changing into something else. Georges Cuvier mocked Lamarck's evolutionary theorybut eventually he found the evidences to support this theory in spite of proving it wrong (Bowler & Morus, 2005; Fara, 2009). So, the data that were initially thought to raise question the idea of evolution eventually came to its support.

9. Science Cannot Answer all Questions

Science cannot answer all the questions and cannot explain all the phenomena of society because sometimes the methods of science are not applicable. And at some places the evidences are not hard to find but can be answered in future. As an example we can consider instances like value of Art, issues of morality, religious beliefs, etc. McComas and Kampourakis(2015) gave an example of Richard Owen who proposed a basic pattern for all vertebrate animals – the vertebrate archetype. This was an idealized model of the simplest conceivable vertebrate from which all real vertebrate species were adapted modifications. According to him the primitive fish possessed the simplest modifications and the humans the most. And this is designed by the God or creator. Owen also gave the idea that combinations of bones can be modified in different species adapted to different environment. And each species was a distinct part of the divine plan (Bowler & Morus, 2005). Such plan exists or not cannot be answered by science yet.

Conclusion

Nature of Science is a very crucial element of the science learning and science processes. And it is crucial to inculcate the proper understanding of NOS among the students as well as in the teachers. As we can see the method discussed above to use of history of science as a tool in class to explicitly enhance the understanding of NOS among students can be very effective. All the examples were taken to engage the students as well as to have a content rich discussion in classroom. All the above mentioned examples were not the only examples there are many more examples that can be used by the teachers. McComas and Kampourakis(2015) had selected works of Mendel, Darwin, Newton etc because they are often mentioned in our regular textbooks. Teachers should try to use different other stories

to discuss in classroom to enhance the understanding of the NOS among the students. As it is mentioned in NCF (2005) also to inculcate the art of learning among the learners and gave them opportunity to enhance their learning. And every classroom transaction should be learner centered. Using history of science also engage students well in the classroom and also help them to understand different aspects of the Nature of Science. The core implication of this article is when a teacher teaches in class the different concepts of biology and mention historical figures, teachers should take is an opportunity to use relevant stories to teach about NOS.

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