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Teaching teachers and students about the nature of science

Nelofer Halai

Aga Khan University, Institute for Educational Development, Karachi

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Nelofer Halai*

Abstract

This article advocates the teaching about the nature of science to both pupils in schools and teachers in teacher education institutions in Pakistan. Not knowing about science; teachers tend to continue to teach science as fixed knowledge and not as inquiry and this cycle continues. This cycle needs to be broken. This article first discusses the salient features about the concept of the nature of science and then illustrates these ideas with the help of a simple but a powerful activity which could be used both with teacher educators and pupils in secondary and lower secondary classrooms.

Introduction

The purpose of this paper is to advocate that teachers be encouraged and helped to develop an overt and clear understanding of the methods and structure of science, i.e., the nature of science. I have tried to define the concepts that constitute nature of science essential for school science. I also want to highlight some of the challenges faced in attempts to introduce the concept of the nature of science in inservice teacher education in Pakistan. I will end by illustrating the nature of science by an activity that could be used to teach this idea to both teachers and students.

Teacher education programmes in Pakistan do not include the nature of science as part of their syllabus. However, Government of Pakistan science curriculum for pupils from classes one to eight does include this topic within the general area of "scientific literacy" as one of the aims of teaching science (Government of Pakistan, 1993). My experience has shown that science teachers in Pakistan have not given sufficient attention to this essential aim of science education because their own experiences as science students has not prepared

* Associate Professor & Coordinator AKU-IED PhD Programme, The Aga Khan University, Institute for Educational Development Karimabad, Karachi – 75950, Pakistan (nelofer.halai@aku.edu)

them to deal with this component of science. Furthermore, preservice and inservice teacher education programmes do not prepare teachers to teach *about* science – the focus is more on methods of teaching and science content.

Need to include the Nature of Science in Teacher Education

Educational innovations cannot succeed if teachers are not taken into account is a lesson that is being slowly learnt. Hence, if change is to occur in the way science is taught it has to be mediated through the teacher (Waters-Adams, 2006). Only by bringing a change in the teacher's way of thinking, will the change be long lasting. Another reason that I advocate a reconceptualization of teacher knowledge about the nature of science is because it is always present as the "hidden" curriculum (Eggleston, 1977; Lakomski, 1988). The nature of science has never been absent from the curriculum, it is just never explicitly stated (Hipkins, Barker & Bolstad, 2005).

Including the nature of science in school science is not a new or novel idea. Educators, professional organizations and science educators have been advocating it for now more than 30 years. Many different professional organizations such as the Association for Science Education (ASE, 1981) in Britain, the American Association for the Advancement of Science in America (AAAS, 1989, 1993) and the National Science Teachers Association (NSTA, 1982, 1995) have reached a consensus on the need for teaching about the nature of science in school. Despite the prevailing consensus there is ample research evidence to show that irrespective of academic background science teachers possess a limited knowledge about the nature of science (Elkana, 1970; Rowell & Cawthorn 1982, Brush, 1989; Mellado, 1997). Not having an understanding of the nature of science is a problem because the teachers' views of the nature of science (or any other subject) can and does influence their students' conceptions of science. Hence, it is not surprising to find that our pupils have misconceptions about the nature of science (Aikenhead, 1973, 1987; Clough, 1997; Lederman, 1992). Not knowing *about* science the science teachers continue to teach science as a collection of facts. The vicious cycle of science-as-collection-of-facts approaches to science teaching breeds students who go on to become

teachers who emulate their teachers, and the cycle continues. It is important that this cycle is broken.

What is meant by the Nature of Science?

The dilemma is that before an understanding of the nature of science can be fostered in students, the science teachers need to have a fairly sophisticated understanding of it. The nature of science because it is both a problematic and contentious concept is difficult to define (Duschl, 1990). However, science educators agree that there is a measure of agreement on a number of points relevant to the school science curriculum (Hodson, 1985, 1991). The National Science Teachers Association of America in a position paper (NSTA, 2000) has listed the concepts of the nature of science that are important for school science. I have provided, below, an abbreviated copy of this list:

- Scientific knowledge is simultaneously reliable and tentative.
- Although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspectives characterize a scientific approach to understanding nature.
- Creativity is a vital ingredient in the production of scientific knowledge.
- A primary goal of science is the formation of theories and laws, which are terms with very specific meanings.
- Contributions to science can be made and have been made by people the world over.
- The scientific questions asked, the observations made, and the conclusions in science are to some extent influenced by the existing state of scientific knowledge, the social cultural context of the researcher and the observer's experiences and expectations.
- The history of science reveals both evolutionary and revolutionary changes. With new evidence and interpretation, old ideas are replaced or supplemented by newer ones.

Challenges Faced in Teaching about the Nature of Science

While teaching a science methods course at the Aga Khan University, Institute for Educational Development, I studied three elementary teachers' developing understanding of the nature of science (Halai, 1999). The predominant mode of data collection was interviews. The analysis of the data gives some understanding into how elementary teachers, who do not necessarily have preparation in science, learn about the nature of science in the context of Pakistan. The findings indicate that practical, hands-on activities are helpful, but there is a need for more overt teaching of this concept and explicit discussion about it after the conclusion of the activity. The two teachers who did not have a background in science had difficulty in border crossing from their own subject sub-culture/s to the culture of science. But the surprising finding was that the third teacher who was a science teacher had greater difficulty in accepting ideas about the nature of science such as: most scientific observations are theory based and science is tentative. It is my conjecture that the science teacher being socialized in a very positivistic conception of science had more difficulty in changing beliefs, as compared to the other two teachers, who did not have much experience of learning and teaching science.

This study clearly indicates that science teachers need to first build their understanding of the nature of science through clear and hands-on activities and then would they be able to teach it to their students in school. The activity given below has the modest aim of illustrating the teaching of one aspect of the nature of science, "scientific knowledge is simultaneously reliable and tentative", with the help of a very simple activity using everyday materials (Flick & Lederman, 2005). This activity is generally called the "Black Box" activity and can be used to help teachers to understand and then to teach this concept to their students. This activity works best with pupils of class 6-8 classes, however with modification it can be used both for younger and older children.

Black Box Activity

The black box activity offers challenges similar to those that scientists face in trying to uncover the secrets of nature (McComas, 1998). A basic black box can be created from very simple materials.

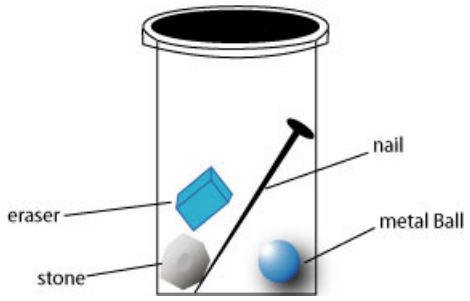

Figure 1: Black Box

i. Take a black empty film canister; make sure that you do not take the white translucent container but the black one. Most photographic material shops are happy to give away these canisters free of cost. Put at least four small objects in it such as a (a) paper clip or a common pin, (b) a metal ball bearing or glass bead so that it can roll easily, (c) a small uneven object like a stone and (d) something soft like a piece of a rubber eraser.

ii. Seal the canister very tightly with tape so that students cannot open it.

iii. For most effective results divide the students in groups of three or four and distribute one "black box" to each group.

iv. The task before each group is to use their senses to identify the objects inside the box. Under no circumstances are they supposed to open the box, but they can shake, roll or manipulate the box in different ways. They are free to talk and discuss their ideas within the group. As a final result they are to make a model of the objects within the box in the form of a pictorial diagram. Allow plenty of time for students to talk and seek empirical evidence for their "theories" of what is inside the black box. Note that I use the word theory to mean an explanation of their ideas.

v. After all the groups have completed the task invite at least four groups to come to the black board and explain their groups' ideas of what is in the box with the help of a pictorial diagram. Try to take groups which have same and dissimilar ideas about the contents of the block box.

From the oral presentation and the diagrams it will become clear that most of the groups are in consensus about a number of things such as: (a) there are more than one item in the box (b) that there are 3-4 items in the box (c) that at least one item in the box is a metallic object (d) at least one object in the box can roll and hence it is likely to be a spherical object. It is important to emphasize that despite the lack of direct visual evidence students' have been able to use their senses and their prior experiences to develop their "theories" about the constituent parts of this "scientific puzzle". It will also be clear that there will be some differences of opinion too in the way some groups have "discovered" what is in the box. Despite these differences a broad "theory" about the constituent elements of the box could be put forward. The teacher can now pretend to end the lesson. The students will immediately request the teacher if they could now open the black box to see if their theories about the contents of the black box is right or wrong.

Here lies the most important part of the lesson

I would encourage the science teacher not to open the "black box" but discuss how scientists work by using their senses or extending their senses with the help of instruments to "guess" the components of some elements of nature. However, often the scientists cannot open that item to see if what they had guessed was actually true or not. They have to live with their guesstimates and use other means to validate and confirm their views. One example the teacher can use to explain this is that scientists for long have conjectured about the constituent gases composing the Sun but no one has had the opportunity to take a direct sample of the gases making up the Sun's surface. This is one reason science will always be tentative. That does not mean that "anything goes" or that it is unreliable. Because of the "self regulating" process built into science through peer review and publication it is hard (but not impossible) to pass off less than reliable results to the scientific community. The students realize that no matter how sure they are about the contents of the black box they could never be 100% certain and hence there was always the chance that in the light of new evidence they would have to revise their view of what forms the contents of the box.

This activity could also help students to learn about models. The models that scientists develop take many different forms. In some cases they are actual physical constructions, such as the model of an eye that is often used in a science class. Other models may be more mental images that are developed in an effort to picture something unseen. A good example would be the Bohr solar system model of the atom that is often used by beginning chemistry students. In this model the nucleus is imagined to be like the sun and the electrons are shown as spinning around the nucleus like the planets moving around the sun. The model that students draw of the contents of the black box would also represent a mental image of their "theories".

This activity and many other such activities can be used in teacher education programmes to serve two purposes. First, to enhance the teachers' own understanding of the nature of science and secondly, to provide them a repertoire of activities that can be conducted in class at various levels to enhance students' understanding of the nature of science.

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