Sample Submission

Errors in Science and Their Treatment in Teaching Science

Why Study Scientific Errors?

In the last decades, the subject of scientific error has been extensively covered in both scholarly and popular literature. A review of this literature shows, however, a considerable confusion about what 'error' actually is. For instance, some authors place under this label old scientific theories (geocentric system, phlogiston, the ether, and others) and pre-scientific views, such as astrology and alchemy (Grant 2006, Jastrow 1936). Others fuse old theories, false discoveries, and experimental errors with hoaxes and UFO (Brown 1998, Smith 2001, Youngson 1998). Still others conflate false discoveries with 'fraud', and 'misconduct' (Kohn 1986). Some authors separate a 'bad' (but honest) science from a fraudulent one (Dewdney 1997), while others introduce a special term 'misconceptions' to denote old theories (Krebs 1999), and still others do not distinguish fraud from misconduct (Judson 2004).

Teachers' Interests

So far, incorporating the subject of error into science education apparently has been limited to errors of measurement (Zachos et al. 2003) and ethical issues (Kowac 1996).[1] However, there are other issues of no lesser interest to teachers, especially those who are trying to incorporate elements of the nature of science in their science courses. Indeed, there is hardly a topic in this area, which can be dealt with without mentioning the notion of scientific error. For instance, when talking of one theory replacing another, students may ask: 'Was the old theory replaced, because it was erroneous?' Or, seeing that their textbooks do not mention scientific errors at all, students may ask if such errors occur very rarely. They are connected, because an improvement in teaching is based on the understanding of the origin of errors. In turn, to understand the latter it is necessary to know how scientists do research, because, as shown below, errors are a natural component of doing research. Thus, teaching about errors is recommended by many as a part of teaching of the nature of science.[2]

Uncovering an Error

Verifiability

Of all the aspects of error, sociologists focused on scientific 'misconduct' and fraud. Some of them claimed that it was verifiability of scientific results that prevented fraud:

> The virtual absence of fraud in the annals of science… appears exceptional when compared with the record of other spheres of activity… Involving as it does the verifiability of results, *scientific research is under the exacting scrutiny of fellow experts*. Otherwise put…the activities of scientists are subject to rigorous policing

> to a degree perhaps unparalleled in any other field of activity. The demand for disinterestedness has a firm basis in the public and testable character of science and *this circumstance, it may be supposed, has contributed to integrity of men of science* (Merton 1973, p. 276).

Thus, scientists see replication of experiments as a tremendous loss of time without getting any credit for it. As some say: 'Such is the evaluation of the situation in modern science' (Broad & Wade 1982, p. 215). Let us now see the situation with verification in the old science.

Verifying a Phenomenon

A phenomenon was usually verified when the author's interpretation of its nature appeared dubious, as shown for several phenomena of magnetization.

In 1751, Benjamin Franklin (1706-1790) discovered magnetization of steel needles by an electrostatic discharge running through their length (Franklin 1752). The magnetism was the strongest if the needle was placed in the direction north-south, and weakest when it was directed east-west. In the latter case, the polarity depended on the direction of the current, however, when a needle lay in the direction north-south, whatever the direction of the discharge, the northern end of the needle always became the north pole. Franklin thought the magnetization to be a direct effect of electricity, and so did the French scientist Thomas-François Dalibard (1703-1779) who repeated the experiment. However, Franz Ulrich Theodorus Aepinus (1724-1802), a member of St. Petersburg Academy of Science, supposed that the actual magnetization was accomplished by terrestrial magnetism with electrical discharge merely facilitating movement of the magnetic fluid, similarly to hammering a steel bar (Aepinus 1979).

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1 Actually, the authors' interest in the subject of error is not limited to errors of measurements. This paper 'is intended to serve as a prelude to more extensive examinations of the role of error in science and science education' (Zachos et al. 2003, p. 954).

2 See for instance Christie (1826), Dyson (1993), Judson (2004), Kipnis (1996), Provostay & Desains (1849).