# Science, Technology and the Teaching of Values[1]

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## *1. Introduction – values and the science and technology curricula*

There is widespread agreement that one of the main aims of basic education should be to equip children in schools with values and attitudes that will enrich their own lives, and enable them, as thoughtful and sensitive citizens, to contribute to the maintenance of society. The main problem with values education is therefore not its justification, but rather how to position it on the curriculum, and how to teach it in the classroom.

One strategy is to integrate it into all other subjects, and thus permeate it throughout the curriculum, rather than give it an allotted time-slot on the school timetable. Though there are well-documented problems with the notions of 'integration' and 'permeation', and their curricular implementation (Pring, 1973, p.123), this is the strategy adopted by the Curriculum Development Council in Hong Kong, in the new education reforms. The eight Key Learning Areas (KLA's), one of which is Science Education and another Technology Education, provide 'the context for the development and application of … values and attitudes' (CDC[a], 2001, p. 22). Well, we might ask, how are science and technology teachers going to do that?

An approach advocated by CDC, which has been used elsewhere, is to focus on the *impact* of science and technology on our lives, and build units of work on these 'science and society' themes into the science and technology curricula. One problem with this approach is the inherent difficultly in trying to come to an informed and reasoned assessment of that impact. This seems to be recognised in the example given in the CDC handbook of *Exemplars* (CDC[b], 2001, p.53), where students are encouraged, for example, 'to keep an open mind but remain sceptical' on whether or not to avoid genetically modified foods. A deeper problem with this approach is the temptation to separate 'fact' from 'interpretation' and thus from theory and value. In that same example, in Step 1, students are invited to 'express their opinions' and, in Step 2, to 'collect their classmates' opinions'. In Step 3 students are then asked 'to search for more scientific facts and evidence' before, in Step 4, considering whether they wish to 'refine' their previous viewpoints. The aim here, of encouraging informed decision-making, is highly laudable. The implicit message, that scientific 'facts and

evidence' provide a neutral touchstone of truth, is highly misleading. Facts always involve a degree of interpretation and therefore are, to a degree, knowledge-dependant and value-laden.

Furthermore, this approach can become rather depressing if it focuses exclusive on, for example, the environmental damage allegedly caused by science and technology, or the vast amounts of research funding devoted to the science and technology of war. It is as though science and technology are being called to 'confession'. These sentiments certainly came to the fore in the previous century, prompting CP Snow, among others, to deplore the clash between the 'two cultures' of science and the humanities. It is not without justification that the First World War came to be known as the 'chemists' war' and the Second World War as the 'physicists' war' (Rose and Rose, 1970). Perhaps we are now witnessing the 'information technologists' war' in the so-called war on terrorism? So, if '*Exploring new scientific developments and demonstrating concern about their impact on society'* (CDC[b], 2001, p.53) is to be the approach adopted in integrating values and attitudes into science and technology, we must recapture Francis Bacon's seventeenth-century vision of science as liberating humanity from its many social and physical ills. There is something to celebrate about the impact of science and technology, just as there is something to caution about.

The line that I wish to explore in this paper, however, is somewhat different from the 'science and society' approach, though it partly arises out of it. I want to begin by going back to the Second World War and the debate about the 'two cultures'. In particular I want to revisit the highly acclaimed paper on *The ethos of science* by sociologist Robert K Merton, and a small, popular book on *Science and human values*, written by Jacob Bronowski, scientist and distinguished broadcaster on science and the arts at that time. Both authors claimed that science, as an institution, has a discrete ethos or set of values, stemming from its distinctive methodology, which guides its practitioners in their quest for knowledge. If this claim is valid, or, as I will argue, some version of it is valid, it may open the way to a potentially productive framework for teaching values in science and technology lessons.

### *2. RK Merton - The ethos of science*

Merton's paper was written in 1942, and that provides an important context. Europe has been at war for three years, and America has been agonising on whether to enter. More

specifically, there is a very real concern within the scientific community, based on the evidence of physicists such as Einstein who fled to America, that Germany was well on the way to producing an atomic bomb. From the public perspective, largely unaware of that nightmarish threat, the armaments used by Hitler in conducting his war are clearly the products of science and technology. For these reasons, and others, science is under attack. Merton refers to 'incipient and actual attacks on the integrity of science' resulting in scientists being 'jarred into a state of acute self-consciousness'. In his later edition of the paper he adds the footnote: 'Since this was written in 1942, it is evident that the explosion at Hiroshima has jarred many more scientists into an awareness of the social consequences of their works' (Merton, 1972, p.65).

Merton's concern, however, is not to address the social consequences of science but to identify its internal institutional ethos. Whatever the results of science, he believes there is something about the way it organises its activities that largely sets it apart form other areas of inquiry and indeed sets it above them, morally. There are four sets of institutional imperatives that together comprise the ethos of modern science. These are:

- *Universalism* – the universally agreed rule of science that 'truth claims, whatever their source, are to be subjected to *pre-established impersonal criteria*; consonant with observation and with previously confirmed knowledge' (ibid., p. 68). 'Objectivity precludes particularism' (ibid, p. 69). As a result, race, religion, nationality, class and any other personal qualities are irrelevant to science, as is personal status within the scientific community, what matters are the truth claims and whether they hold up to scrutiny.
- *Communism* – in the sense of common ownership of the products of science. Unlike technology, the 'scientist's claim to "his" intellectual "property" is limited to that of recognition and esteem' (ibid, p.72). Knowledge within science, once declared to the scientific community, becomes the property of the community.
- *Disinterestedness* – not to be confused with personal altruism, the institutional imperative is that, whatever their personal motives, the stance of the scientist with regard to his quest for knowledge should always be disinterested – seeking the truth wherever it should lead. This norm, Merton believes, helps to explain why fraud in science is rare, for, as the

results of science are open to public test, 'the activities of scientists are subject to rigorous policing, to a degree perhaps unparalleled in any other activity' (ibid, p76).

- *Organised scepticism* – the 'suspension of judgement until the facts are at hand' (ibid, p.78). Scientific knowledge claims, including one's own, must not be taken on trust, but should be continually scrutinised for logical consistency and empirical accuracy.

***3. Jacob Bronowski – science and human values***

Bronowski is perhaps better known for his highly acclaimed television series and accompanying book *The ascent of man*. The three essays that comprise his *Science and human values* were first presented as lectures, in 1953, when he was Carnegie Professor at the Massachusetts Institute of Technology. Their origins, however, are in the visit he made to Nagasaki, in November 1945, as an official observer of the damage done by the dropping of the atomic bomb. Like Merton, he is very mindful of the accusing fingers pointing at science and, in similar fashion, he turns to examine the institution of science to make his response.

Bronowski is at pains to point out that science, no less than the arts, results from creative processes of mind. It may seem strange to us that he has to emphasise this point, but the image of science prevalent at that time was one in which science was viewed as a collection of incontrovertible facts about the world, and the scientist as somebody who simply observes the facts that Nature 'reveals' when conducting his or her laboratory experiments. That image has not completely evaporated, even today, as we noted earlier in regard to the notion that facts in science provide a neutral touchstone of truth.

Bronowski focuses on the discovery of new scientific theories and argues that 'no scientific theory is a collection of facts. It will not even do to call a theory true or false, in the simple sense in which every fact is either so or not so'. Scientific discovery results from:

> a new order which gives unity to what had long seemed unlike. Faraday did this when he closed the link between electricity and magnetism. Clerk Maxwell did it when he linked both with light. Einstein linked time with space, mass with energy, and the path of light past the sun with the flight of a bullet... (Bronowski, 1964, p.25).

He then identifies this same process in the work of great literary writers and poets, and concludes that '*there is a single creative activity which is displayed alike in the arts and in the sciences*' (ibid, p.31 [italics added]).

In the second chapter, however, where he considers what he calls 'the habit of truth', Bronowski draws back from this earlier assertion when he argues that the 'creative act is alike in art and in science; *but it cannot be identical in the two*; there must be a difference as well as a likeness.... The sanction of truth is an exact boundary which encloses him, in a way in which it does not constrain the poet and the painter.' (ibid., p.32 [italics added]). It is with this notion of the 'institutional sanction of truth', and his belief that norms and values of science are essentially institutional and derive from the distinctive methodology of science, that Bronowski comes closest to Merton, though he makes no reference to him.

> The values of science derive neither from the virtues of its members, not from the finger-wagging codes of conduct by which every profession reminds itself to be good. They have grown out of the practice of science, because are the indispensable conditions for its practice.... Truth is the drive at the centre of science; it must have the habit of truth, not as a dogma but as a process (ibid., p.66).

### *4. Problem with the functionalist analysis and the epistemological base*

The claims made by both Merton and Bronowski were accorded considerable contemporary acclaim, though with rather different audiences. Bronowski's appeal was to the educated man in general. Merton's paper gave rise to a considerable research programme in sociology, conducted along similar functionalist lines. Merton's thesis was, however, challenged from within the functionalist tradition by Mitroff's (1974), who argued that for each of Merton's four imperatives one can identify, in the actual practice of science, an equally powerful but opposite imperative. Thus while the norm of universalism may hold sway on many occasions, the opposite norm of particularism will operate whenever scientists, for perfectly sound and rational reasons, decide to judge knowledge claims on the basis of personal criteria. Similarly, common ownership of knowledge is frequently balanced by a norm of secrecy, and so forth.

Both Merton and Bronowski relied heavily on the then widely accepted empiricist epistemology. Specifically, both placed considerable weight on the empiricist notion of

scientific method, on the independence and neutrality of observation, on the correspondence theory of truth, on the decisive role of empirical evidence in verifying truth claims, and on the need to fundamentally separate fact and theory, fact and value. Though purporting to be descriptive of science, these empiricist claims were undermined as philosophers of science progressively turned to the history of science to reconstruct their accounts of the nature and progress of science. Probably the most famous among these was Thomas Kuhn's *The structure of scientific revolutions*, first published in 1962, but many other scholars contributed to the debate that reached its height during the 1960's and 1970's, including Karl Popper, Imre Lakatos, Paul Feyarabend, Michael Polanyi, and Mary Hesse.

Building directly on the new philosophy of science, sociologists also began to look very closely at their own work, and this resulted in a strong critique of functionalist approaches to the sociology of science. In particular, the new sociologists of knowledge questioned the assumption of most functionalists that while one could investigate the institutions of science one was powerless to comment on the processes of knowledge production, for, it was believed, knowledge in science is not socially constructed but is instead a matter of objective fact. As Michael Mulkay recalls:

> Clearly a major barrier preventing sociologists from exploring these possibilities is likely to be epistemological in character. One would not hesitate to consider such possibilities with respect to "inferior" forms of knowledge. The difficulty with respect to science is that we are departing from a well-entrenched epistemology. We are assuming that scientists' accounts of the natural world are not to be taken simply as reflections of objective reality, nor as determined by invariant and transcendent rules of evidence. We are treating the notion of 'consonance with observation', for example, as being sociologically problematic. It is not surprising, therefore, that sociologists did not venture to pose questions of this kind until the ground had been prepared for them by a series of debates among philosophers and historians, in the course of which the customary view of science was seriously challenged (Mulkay, 1979, p.26).

Particularly penetrating were the philosophical concerns regarding the notion of objective truth, and the division of fact from theory. Recall how both Merton and Bronowski had insisted that the fundamental difference between science and other forms of knowledge lies in the method of science, which is directed at establishing objective truth on the basis of impartial, unbiased observational evidence. Thus, Merton's insists that 'objectivity precludes

particularism, and that truth claims in science must be 'consonant with observation'. Similarly, Bronowski separates fact from theory. Facts, he believes, are firmly grounded in truth, and it is the 'sanction of truth' that separates science from other forms of knowledge.

From a commonsense point of view, of course, when we observe the world carefully and with an open mind we are viewing it neutrally, as it really is. Our eyes provide an image of an object and that image is then conveyed to our mind in a fairly straightforward way. Based on this commonsense assumption, the 'correspondence theory of truth' asserts that a statement is true if, and only if, it accords with the observed facts. It is this concept of truth that underpins the arguments of both Merton and Bronowski. Observation, however, is never as straightforward as this view maintains. We are never in a position to view the world from a neutral standpoint; we must always view it within an interpretive context that in large measure is a result of our previous experiences and present expectations. That is a fundamental aspect of human experience, and it applies to all areas of human knowledge and inquiry, including science.

At this point, I am grateful to Professor John Osborn for pointing out that criticisms levied against the empiricist notion of truth do not directly undermine Merton's thesis, despite claims to the contrary. The reason is that most scientists are realists and espouse the correspondence theory of truth, even though it is philosophically suspect. Merton's thesis is describing how the scientific community functions, not prescribing how it should function, and scientists are free to ignore the concerns of philosophers in pursuing their institutional norms and values. That is an important qualification, though it would surely be better for science if its norms and values could be more securely founded. I also think it is better for humanity if, instead of constantly emphasising the differences between subjects, we concentrate more on those things that all forms of human inquiry share.

***5. Shared values of scholarship across the curriculum***

Bronowski first asserted that creativity is alike in the arts and in the science, but then drew back from that position and claimed that science is special and different, because its tests for truth are different. I want to suggest that this was a mistake, and that his basic intuition in favour of a more holistic and unified concept of human knowledge and creativity was

correct. There has always been a tendency within philosophy of science to seek criteria of demarcation between science and all other forms of knowledge. It has its roots in the seventeenth century when the new science was trying to establish itself, and it had its hey day with the claims of positivism that only those statements that are in principle verifiable make sense; all else is non-sense. For the positivist, scientific statements make sense while value statements are expressions of subjective emotion. Bronowski's book was written when positivism was at its peak. Judged from that standpoint, one can appreciate his earnest attempt to find similarities rather than differences between the sciences, humanities and the arts, despite the divisive claims of positivism. Consider, for example, how he describes the particular virtues of the scholar.

> By worldly standards of public life, all scholars in their work are of course oddly virtuous. They do not make wild claims, they do not cheat, they do not try to persuade at any cost, they appeal neither to prejudice nor to authority, they are often frank about their ignorance, their disputes are fairly decorous, they do not confuse what is being argued with race, politics, sex or age, they listen patiently to the young and to the old who both know everything (Bronowski, 1964, p.64).

If one were to stop at this point, and substitute the word scientist for scholar in the first line, one might be excused for believing that Bronowski is largely reiterating the institutional norms identified by Merton as distinctive of science. But he is not, for he goes on to insist that: 'These are the general virtues of scholarship and they are particularly the virtues of science' (ibid.). In other words, there are certain values that underpin all scholarship, all forms of serious intellectual inquiry, and these, Bronowski, believes, are particularly exemplified in science. Personally, I see no reason to make that extra claim for science.

I began this paper by referring to the requirement in Hong Kong that the eight KLA's integrate values and attitudes into their curricula, and I asked how science and technology educators might achieve that? I suggested that revisiting the work of Merton and Bronowski might furnish some clues. My proposal is that if Bronowski's intuition is correct and there is a single creative activity which is displayed alike in the arts and in the sciences, and all forms of intellectual inquiry share much the same values, then *the call to **'integrate'** values into the curriculum may be eclipsing the need to **draw out** those values that are already there, inherent in all subjects.* Students should be encouraged to see that underpinning each

academic subject they study in school there is much the same set of values, and that these are institutionally binding, as both Merton and Bronowski claimed in regard to the values underpinning science.

Is it possible to name those values? I think it is, and, while they share similarities with those identified by Merton and Bronowski, I would emphasise that the way they are manifested may change over time, and so they are not as static as Merton and Bronowski supposed. They may also be contested in specific contexts of inquiry, as Mitroff pointed out in regard to Merton's four norms, and they may also operate differently in different social and cultural contexts. I suggest these eight:

- Intellectual *Curiosity* - the individual and collective quest to inquire and discover, the seeking for patterns in phenomena and the creation of meaning;
- Intellectual *Love* – the dedication to the quest for its own sake and the joy of discovery. The love of the natural world and its creatures as the object of inquiry;
- Intellectual *Freedom* – the freedom to pursue our ideas and our research inquiries wherever they may take us;
- Intellectual *Honesty* – the imperative not to cheat in the claims we make for our own originally and to give credit where it is due;
- Intellectual *Respect* – for the natural world and for the dignity of all who are seriously engaged in the processes of inquiry;
- Intellectual *Co-operation* – the willingness to share the fruits of ones own investigations and to work collaboratively with others;
- Intellectual *Tolerance* – of the views of others while engaging in critical debate about their views.
- Intellectual *Humility* – the awareness that our knowledge and understanding is limited, and however firmly we believe we are right, we accept we may be wrong.

How can these values be brought to the attention of students in our classrooms? At one level, of course, they will be exhibited by all good teachers of science and technology in the way they act, and in what they say to students in presenting the topics they teach. But teachers need to make them explicit, to be sure that students are noticing them. Students should be

taught that the reason they should not copy the work of others and claim it as their own, should work cooperatively and not be intolerant, and so forth, is not simply because the teacher says so, but because that is how the academic community functions – and they are being inducted into the norms and values of that community in their studies at school.

These values should also be brought to the fore in science and technology textbooks, and used as a basis for classroom discussion. They can be introduced in the form of short case studies in the history of scientific research and discovery. Students will learn much about the dynamics of research and discovery by being shown how these values come under strain when, for example, claims for original discovery are contested, or as individual scientists make judgements on whether or not to cooperate on a research project. These kinds of issues, if properly presented by the teacher, can give rise to lively debate among students. At the same time, students should be encouraged to see that the sharing of these values across all communities of inquiry is indicative of the unity of all human knowledge and understanding. And, that the values underpinning scholarship are also values that underpin our common humanity, whether we abide by them, or not.

## Note:

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