Comment

Getting Scientists to Think About What They Are Doing*

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ABSTRACT: *Research scientists are trained to produce specialised bricks of knowledge, but not to look at the whole building. Increasing public concern about the social role of science is forcing science students to think about what they are actually learning to do. What sort of knowledge will they be producing, and how will it be used? Science education now requires serious consideration of these philosophical and ethical questions.*

But the many different forms of knowledge produced by modern science cannot be covered by any single philosophical principle. Sociology and cognitive psychology are also needed to understand what the sciences have in common and the significance of what they generate. Again, traditional modes of ethical analysis cannot deal adequately with the values, norms and interests activated by present-day technoscience without reference to its sociological, political and economic dimensions.

What science education now requires is 'metascience', a discipline that extends beyond conventional philosophy and ethics to include the social and humanistic aspects of the scientific enterprise. For example, students need to learn about the practices, institutions, career choices, and societal responsibilities of research scientists, and to rehearse in advance some of the moral dilemmas that they are likely to meet. They need also to realise that science is changing rapidly, not only in its research techniques and organisational structures but also in its relationships with society at large.

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1. "What do you think you are doing?"

When somebody shouts at you "What *do* you think you are doing?" they really mean "Stop doing it at once!" But if you don't want to stop doing whatever it was, you are entitled to treat it as a question, and counter with an explanation, such as, "I was only admiring your lovely garden," or "You have a crumb on your lapel," or "If I hadn't grabbed you, that car would have knocked you down." Unfortunately, many of the exchanges between scientists and other citizens don't get to this second stage. That's a pity, because scientists mostly do have quite reasonable explanations for their activities, whether as research or as practice. Sometimes, as currently with the genetic modification of organisms, these explanations do not ward off opposition, but at least they open the way to creative dialogue. That is what democracy is all about.

Experienced operators at the interfaces of science and society build up a repertoire of stock answers to the most frequently asked questions. These answers are not necessarily fully convincing, but they serve to indicate that the work is well motivated and designed to achieve morally desirable ends, such as alleviating famine or saving the environment. Scientists who come newly into these fields quickly learn the appropriate responses, and the debate continues on predictable lines.

The trouble is that the pace of scientific and technological change is now so rapid that it outruns this process. Quite new technical procedures, consumer products, practical inventions, intellectual concepts, social institutions, etc. keep coming up and raising serious societal issues that have never previously been considered. Take, for example, the legal conundrums surrounding authorship on the internet or the theological dilemmas posed by the cloning of human tissue. These issues have emerged so rapidly that the relevant scientific authorities have simply not had time to think out their position on them before they get decided by more self-interested or doctrinaire contestants.

What should be done? For some years I ran the Council for Science and Society, a voluntary non-governmental organisation that tried to look 'over the horizon' for such issues before most people became aware of them and to develop some rational discourse about them. But this was a thankless task, which died for lack of funding – although I notice that a Report from our House of Lords is now recommending the formation of just such a body, as if no one had ever thought of such a thing before. We were only 25 years ahead of our time!

However, this seminar series is an opportunity to develop another old idea about how to deal with the same problem. In the 1970s some of us talked a lot about the need for "Teaching and Learning about Science and Society". In fact, that was the name of the book that I wrote in 1980, exploring this theme. In essence, the idea was that education of science students, through school and university, was so narrow and specialised that they never got a chance to think more broadly about their future careers. As a result, when they were unexpectedly challenged about their work, they had no framework of knowledge or opinion in which to locate a reasoned response. So what was needed was an additional module in the science curriculum where issues of this kind – Science, Technology and Society (STS) issues as they are often called – could be discussed seriously, and where at least some of the appropriate reactions could be rehearsed beforehand. I didn't say that they could be trained to give the 'correct' answers, because nobody knows what these are, but one might take them, say, five years along the learning curve that they will surely have to traverse in their later careers.

But then, what should this new module contain? There is not much point in just covering all the issues that are currently disputed, because quite novel ones will surely emerge within the careers of our students. Who would have defined cattle feed as a controversial topic before the BSE scandal? And against what scientific discipline will great Thor despatch his next thunderbolt? How about plausible evidence that the Gulf Stream will soon be switched off? Or the invention of an 'elixir of life' that will double or treble the length of human life? We need to prepare our students for the unexpected – the next science war, not the last one.

So the theme has got to be quite general. What could be more general than the *values* that are likely to be in question in any societal issue involving science? As the theme paper of these seminars says, "science and values cannot be separated". And yet we try to teach science as if it were 'value free'. How could anyone possibly explain why they are doing something without reference to the values that motivate their actions? This is the gap that the new module should try to fill. This must be the baseline of any response that our students will be able to make to that harsh demand "What do you think you are doing?"

2. Where do we find values?

Values enter into STS from both sides. On the science side, there are the values attached to the scientific type of knowledge – what I shall call the *epistemic* values. On the side of society, there are the values associated with how that knowledge is put to use – that is *moral* values. This dichotomy is obviously much too crude, since it ignores the reflexive element. In every STS situation, the type of knowledge that is at stake will depend on how it is intended to be applied, whilst the uses to which it might be put will depend on its epistemic status. Technology, the region in the middle, has its own characteristic values, which ought to be brought into the calculation, but let us ignore that complication for the moment.

The notion that students are quite oblivious to any of these values is clearly false. One cannot learn any branch of science, however technical or abstract, without unconsciously imbibing its particular epistemic values. From mathematics, for example, one learns the value of logical precision. From physics one learns the value of quantitative accuracy. From chemistry one learns the value of experimental cleanliness. From biology one learns the value of meticulous observation. From geology, I guess, one learns the value of endless perseverance. From cosmology, I suppose, one learns the value of wild imagination. From palaeontology, I imagine, one learns the value of fragmentary evidence. From anatomy, surely, one learns the value of objective realism.

And so on. The fact is that science students acquire a great variety of genuine epistemic values. Unfortunately, these are as diverse and specialised as the sciences where they are learnt. Some of them are also mutually contradictory. If they were bundled together, many of them would cancel each other out. Elementary-particle physics values completely contrived events: ecology values only perfectly undisturbed nature. Again, which quality of mind has the higher value – imagination or realism? Well, it all depends whether you are talking about the universe or about the pancreas.. So science students don't acquire a complete and consistent set of epistemic values.

When a multidisciplinary issue takes them out of area, they don't know which way to go.

The traditional mission of the philosophy of science has been to discover or construct a compass that will always guide them to the truth. For centuries – perhaps ever since Aristotle – philosophers have been seeking a grand theory of everything scientific, an epistemological master equation from which one could calculate the truth-value of all scientific propositions. All those different epistemic values would then turn out to be just local signposts to the one and only 'scientific method', which could be guaranteed to produce unchallengeable results in all circumstances. So that would solve the whole STS *problematique*. Asked what he or she thought they were doing, a scientist could silence all opposition simply by replying that he/she was applying this method.

Unfortunately, this grand mission has not found its North West Passage. The philosophers have not yet produced a general theory of science. In fact, they are still arguing amongst themselves about many of the items that would appear in such a theory. Their views on the epistemic value of scientific knowledge range over a wide spectrum stretching from strong realism to unconditional relativism, with many shades of scepticism in between. The humble science student entering this academic domain in search of a philosophical ground base will be very disappointed, if not thoroughly bemused, by all this argumentation.

What a philosopher might say is that this exposure to argumentation about the basic epistemic values of science is a good preparation for those tricky questions that will later have to be answered in practice. But that assumes that the philosophers really are arguing on a higher plane of generality than would the scientists in any particular field. Is that a sound assumption? Let us take Karl Popper's well-known falsification criterion. In some disciplines this is a good rule of thumb. In chemistry, for example, one should never entertain a hypothesis that could not in principle, by some means or another, be shown to be quite wrong. But in historical disciplines such as palaeontology this is too restrictive, and in cosmology it would be completely frustrating. Again, the philosophy of science has been so focused on the physical sciences that it makes too little allowance for the innate variability of biological organisms, which limits the possibilities of meaningful quantification.

3. Philosophy as metascience

I have now painted myself into a corner. The philosophy of science does not seem to have a very positive role in science education. What the philosophers say about science might encourage a few science students to think what they are doing, but would merely confuse the majority of them. In order to jump free, I must use a typical academic trick. Whoever said that the philosophy of science was limited to what is said by people who call themselves philosophers? I believe it should be interpreted much less narrowly. In real life, no proposition makes sense without information about its context. We cannot judge whether a knowledge claim should be counted as 'scientific' just by examining it in isolation. We need to know who claims it, how and why they came to do so, what it further implies, and so on. So I would argue that a 'philosophy of science' module for science education should cover all these aspects of the scientific enterprise. I believe that science students should study what I would call 'metascience' – that is, a broad discipline that includes all rational discourse about science in general.

In particular, science students need to know about science as a communal enterprise, with its own characteristic values. They must realise the over-riding importance of open publication, where research findings are presented for public debate. They must understand the part played by peer review in warranting reasonable initial plausibility, and the need both for authenticity and for systematic citation of sources. They must appreciate the meritocratic self-governance of the scientific community and its continual vigilance against material interests that might harm its reputation for objectivity. They should also learn why scientists are mostly extremely specialised in their research, and about the part played by professional 'recognition' in motivating their careers.

Science students should not only get to know about the characteristic traditions, customs, conventions, criteria of achievement, etc. of academic research. They should also see that these can be interpreted sociologically as the practical expression of a set of 'norms' – that is, ideal standards against which we measure the quality of our actions. In science, these norms are the unwritten rules that effectively regulate our 'ordinary' behaviour as scientists, even though they are never perfectly realised in the actualities of daily life. That leads on to the appreciation of the role of social institutions, such as universities, research laboratories, publishing houses, the internet, etc. in the scientific world – a role that is entirely neglected in the standard philosophical curriculum. It also suggests some discussion of the natural capabilities of individual human beings, perceiving the world about them and communicating to each other their interpretations of it.

Conventional philosophical doctrine would have it that these sociological and psychological factors should be rigidly excluded. They are supposed to be quite irrelevant to any answer to the question: "What do scientists think they are doing?" But on further reflection one can see that most of the epistemic values identified by the philosophers of science are meaningless without reference to these considerations. Certainly, the philosophical principles that are supposed to regulate science and to demarcate it from other forms of knowledge have to be consistent with its communal norms and cognitive facilities. I would even say that the epistemic characteristics of scientific knowledge are bound up with the sociological and psychological conditions under which it is produced. Thus, if a scientific proposition is to be communicated to others, survive peer review, and successfully endure systematic public criticism in an open, meritocratic, world-wide community, it had better be lucidly expressed, logically non-contradictory, empirically sound, theoretically convincing, robust against critical testing, etc., just as the philosophers tell it. The philosophical, cognitive and sociological conditions for 'scientificity' are closely linked. But the cognitive and sociological conditions are primary, for they are more in keeping with human realities. They do not pretend to be as rigid as philosophical logic, and thus permit creative behaviour that would otherwise be judged 'unscientific'. For example, scientists favour the provisional publication of contradictory research findings, or of highly speculative theories, if information about these seems likely, in the end, to further the advancement of knowledge.

What is more, a general metascientific approach gets to the heart of many issues that stump the philosophers. For example, the norm of 'disinterestedness' wisely advises against the acceptance of knowledge claims from a 'tainted' source, such as the research laboratory of a tobacco company or of a racialist government, even though these claims may look perfectly 'scientific' in outward form. Again, the issue whether a particular body of knowledge should be dismissed as 'pseudo-science' is best approached by a study of the social conditions in which it was produced. Is it the uncensored, unforced consensus of an open, critical community? Have efforts been made to test its claims independently? Have these claims been thoroughly debated against all rational objections? How well do they accord with larger, previously well-established bodies of knowledge? And so on. The answers to such questions can never decide such issues definitively, but they usually provide us with all the information we need to deal fairly with them in practice.

The particular virtue of this approach is that it provides defences in depth against sceptical relativism. Generally speaking, science students are taught to believe that science reveals the world as it really is. But when they become aware, as frequently happens, that absolute realism cannot be justified by formal philosophical arguments, they are completely unprotected against contrary doctrines. They just have no intellectual weapons against the fashionable notion that the established epistemic values of the sciences are entirely arbitrary, or are so weak that they can be socially deconstructed. To combat such unhelpful doctrines, they need to appreciate that a well-established scientific discipline is a very dynamic and robust institution. Although the knowledge that science produces can never be *perfectly* true, much of it has been as thoroughly substantiated and competitively criticised as human ingenuity can contrive.

The major difficulty in giving a crisp answer to the general question: "What do you scientists think your are doing?" is to indicate clearly (a) that all scientific knowledge is corrigible, but (b) that some parts of it are much more corrigible than others. Science students have to be able to explain how it is that parts of science are as reliable as anything else we believe about the world, whilst other parts need to be taken with smaller or larger pinches of salt. They learn this lesson pretty quickly when they start to do real research, but even then they accept it unwillingly, in relation to the substance of their specialty, and do not realise that it applies quite generally, in every other branch of science. As the physicists say: the theoreticians know all the unstated weaknesses in their theories but accept the experimental data at face value; the experimentalists trust the theories, but are very conscious of the errors in the experimental results. Of course, natural scientists are entirely distrustful of the social sciences, but that is another misconception which a proper grounding in metascience can help to dispel.

To sum up this part of my talk. What science students need is an educational module introducing them to the basic metascientific principles that determine the epistemic values of science. Of all such values, the most important is corrigibility – a quality that applies to the grandest theories as well as to the messiest little facts. What is more, this is the quality that really counts in practice. It requires that the answer to the specific question "What do you, in your study of this particular subject, think you are doing" should go beyond the supposed scientific facts or theories to include an account of the particular grounds on which these facts or theories might be considered reliable and an assessment of their current degree of credibility. This is what determines the true value of the knowledge that scientists actually contribute to society.

4. Ethics, eh?

Now let us look at the STS region from the side of society. What can science education have to say about the *moral* values involved in the use of scientific knowledge. In these lectures, this is the role assigned to *ethics* – that is, the science or philosophy of good conduct. Needless to say, this too is an ancient discipline, which ought to have an honoured place in any educational curriculum. But its basic principles are even more disputed than those of the philosophy of science. I doubt whether most science students would benefit from a course that tried to explicate these principles and disentangle them from their mutual antinomies and paradoxical conclusions. In fact, nothing could be better calculated to induce a cynical, amoral attitude to one's human responsibilities than a genuinely undogmatic course of this kind.

In practice, however, science students are not amoral beings, brought up in an ethical vacuum. They are the products of a lively, articulate, moralising culture. They have already acquired from home, school, church, the media and their peers a set of rules of conduct that will carry them more or less successfully through the challenges of life. These may be mere conventions, mere maxims, mere rules of thumb, with no deep foundations. They are often logically inconsistent. People love animals and eat meat. They pity the poor and buy themselves luxuries. They pray earnestly for peace and go to war. But these happen to be the ethical principles that they have and hold. It is not within our power as teachers – especially as science teachers – to try to change them.

Nevertheless, scientists not only have great difficulty in explaining what they are doing: they also find it difficult to explain why they are doing it. They are not accustomed to articulating the moral values that motivate them. These values are largely taken for granted, and only come into question when things go wrong. It then turns out that many of the social issues involving science are extremely convoluted, morally and ethically. They take time to think through. To prepare themselves for such occasions, science students need to get a feeling for the moral dilemmas that can arise in the application of scientific knowledge to real human problems. In sum, science education ought to include a module on the *practical ethics* of science.

Such a module would inevitably cover typical current issues – genetic biomedicine, environmental degradation, technological disasters, etc. But it would not be designed to provide stock answers to standard problems. It would treat these issues, rather, as source material for case studies raising characteristic types of ethical dilemmas. These take many different forms, such as the conflict between individual and communal rights over birth and death, the weight to be attached to the needs of future generations, the responsibilities of scientific experts as advisers and witnesses, and so on. By rehearsing and analysing his or her response to a few carefully selected practical situations, the student can be sensitised to some of the general principles that are likely to be at stake on future occasions, even though in very different circumstances.

5. Science and scientists in society

Here again, however, the analysis must extend beyond the immediate events to their social context. The ethical conflicts that arise over, say, genetic counselling are often presented as confrontations between individuals with moral principles that just happen to be different. One of the most important things that the student of science has to learn is that the views and behaviour of non-scientists about science and its works are not 'irrational' or dogmatically contrary. In many cases, they have been systematically developed by serious and sincere thinkers and groups in relation to deeply held and well-established principles, such as a religious faith or a humanitarian concern. Education in ethics starts from respect for, and ends with understanding of, the genuine quality of its differences.

From case studies of public ethical conflicts, the student should learn that the contestants are not just responding to peculiarly personal values and interests. They are actually located in societal institutions, such as families, firms, governmental organisations and professions, whose practices and norms they are following. Indeed, outside the classroom or laboratory, science students and working scientists are themselves members of various of these groups, and need to acknowledge that they too share their respective ethical concerns. Thus, for example, biology students learning to do experiments on animals need to come to terms with their own personal feelings about 'animal rights' if they are to deal honestly with ethically motivated campaigners on this issue.

More generally the structural features and social functions of these institutions frame and shape the actions of their members. We have already noted the importance of the communal structure of science in establishing its epistemic values. These values are, of course, vital to our understanding of all STS issues. But many of the corresponding moral values arise out of the way that the sciences and their associated technologies are factored into society at large.

In other words, under the heading 'ethics', I would include systematic study of the 'external' social relations of modern technoscience. 'Academic' science presents itself as 'disinterested', as if entirely disconnected from the 'real world'. But what we loosely call 'science' is a whole complex of human activities, ranging from fundamental research carried out largely by individuals and small groups in universities to technological development performed by elaborately organised teams employed by industrial firms. These activities are threaded together by traffic in ideas, people and instruments. They are also embedded in the society that they serve, whether as educational institutions, producers of public knowledge, or commercial enterprises.

Scientific research, we often say nowadays, is a distinctive, transnational *culture*. Scientists from different countries – countries much more different than Denmark and Britain – can walk into each other's laboratories and immediately feel at home. But this culture is actually divided into numerous subcultures, not only discipline by discipline but by societal location and function. University-level institutions educate students for entry into the research subcultures of a particular discipline. They do this by concentrating entirely on the substance of scientific knowledge and on the techniques of research in that discipline. What science students are taught is that their particular branch of science is unified by certain theoretical paradigms, specialised techniques, unsolved problems and characteristic applications. In effect, they are taught a set of epistemic values which are deemed to be more or less common to all researchers and practitioners in that science.

What science education does not mention is that the different ways of *organising* research actually demand somewhat different patterns of behaviour, with correspondingly different moral responsibilities and ethical codes. For example, 'industrial' scientists owe to their employers a duty of confidentiality that does not apply to 'academic' scientists. On the other hand, 'academic' scientists are expected to be intellectually independent to a much higher degree than their industrial counterparts. This is not to say that academic scientists are never secretive about their research, or that industrial scientists are never truly original or critical. Far from it. But they are regulated by different communal norms and attach different relative values even to their epistemic achievements. Thus, the theoretical breakthrough celebrated in academia may count for less in the industrial world than an ingenious invention with many potential applications, and vice versa.

6. Ethics and interests

This distinction between the various subcultures of science is particularly marked in relation to the role of external 'interests'. This is an issue of fundamental importance. Ethics is very often about the effects of just such interests on our behaviour. A very common answer to the question "Why are you doing that?" is "Because it serves the interests of X", where X is a person or a personified institution. Again, the full answer to the question "What are you actually doing?" is almost bound to include references to the effects of your actions on the interests of other people. Such interests may be direct or indirect, material or intangible, perceived or latent, personal or communal. In every case, they are major factors in the ethical analysis of the behaviour to which they are linked.

Now as we have seen, academic scientists are required to be 'disinterested', not only in the detached way in which they present their findings but also in keeping clear of material influences that might affect their scientific judgement. Industrial scientists, by contrast, are expected to serve loyally the interests of the client, corporation, public agency, or nation that employs them. Academic science is said to be 'pure' to indicate that its has been cleansed of all extraneous interests except the pursuit of knowledge 'for its own sake'. Industrial research is termed 'applied science' to indicate that it is motivated explicitly by quite other interests than the pursuit of knowledge itself.

In reality, this distinction between 'pure' science and 'applied' science has never been perfectly sharp. One of the important lessons that ought to be taught to science students is that much 'pure' science was actually undertaken for quite mundane ends, such as the improvement of navigation. Conversely, some of our most abstract epistemic achievements, such as the Laws of Thermodynamics, came out of very grubby technological enterprises. But until, say, the latter part of the 20th Century, these two sub-cultures were kept somewhat apart. Generally speaking, academic scientists had little to do directly with industrial research and development, whilst industrial scientists did not undertake research that produced public knowledge.

This social segregation of the two scientific subcultures meant that there was seldom any occasion to question the influence of interests on epistemic and moral values. Each subculture had its own way of avoiding this question. On the one hand, academic scientists, being supposedly quite 'disinterested' in their research, could make a plausible claim to the highly-prized epistemic quality of 'objectivity'. Translated into its moral equivalent, 'impartiality', this put them on a pedestal high above mere 'ethics'. Indeed, they trumped all such considerations with the doctrine that science was the way – the only way – to the 'truth', and therefore a pursuit of higher value, moral as well as epistemic, than any other.

On the other hand, industrial science is the direct source of technological innovations that touch human interests to the very depths of life and death. All its doings, whether for good as in medicine or for evil as in war, are therefore of the greatest ethical concern. But industrial scientists could argue that they were so tied to the interests of their employers that they could refer any ethical issues up to the boss and cheerfully get on with doing what they were ordered to do, regardless of its human consequences. This appeal to superior authority – 'I was only obeying orders, Sir' – is not, of course, ethically valid. But it was a plausible way for industrial scientists to be 'in denial' on the momentous effects that their behaviour was having on the welfare of other people.

7. Post-academic science

One can now see why there has been so much resistance to the very notion of teaching about ethics to science students. The two arguments used to shut it out : "We only produce objective knowledge" and: "We only produce knowledge to order" seem plausible enough in their respective subcultures. But these arguments are obviously mutually inconsistent. Put them together in the same course, as one would have to for students who might be entering either subculture, and they cancel each other out. Similar contradictions would appear in discussion of other issues with ethical implications, such as the part played by open publication in the production of knowledge, or the degree to which the goals of research ought to be assessed for potential social disbenefits.

The inconsistent doctrines actually used by scientists and technologists to justify local norms and practices in different technoscientific contexts are tolerable so long as they are never brought together for general ethical analysis. It has always been acceptable – although never easy or popular with students or professors – to teach students who are already well on the way to becoming medical or engineering practitioners about the peculiar professional ethics of their respective trades. Indeed, such courses are now quite fashionable, and have become institutionalised as academic sub-disciplines in their own right. But the ethics of professional practice, with its emphasis on unstinting service to the requirements of a particular client or patient, would give quite the wrong message to the apprentice academic, whose prime loyalty has to be to the austere goddess of abstract Truth. Indeed, the ethical framing of double-blind drug trials is pulled apart by these contrary moral imperatives. Traditional science education, being addressed to both these groups, has always excluded more general ethical studies that might expose these fault lines in its moral base.

But this policy of never discussing ethical considerations is no longer tenable. The division of technoscience into two distinct subcultures is no longer meaningful. For various reasons – which ought to be discussed in the proposed new module – 'academic' science and 'industrial' science are merging into a new societal form – *post-academic science*. This is obvious, for example, in the way that university scientists are being directly funded by the private sector, or are expected to patent their findings and to exploit them commercially. It is evident also in the very advanced 'basic' research undertaken by many industrial firms, and in the way that scientists move back and forth between public institutions and corporate laboratories. What were previously quite distinct social practices are being performed almost simultaneously, day by day, by the same individuals. On Mondays, Wednesdays and Fridays, in my 'academic' role, I write a paper for a learned journal : On Tuesdays, Thursdays and Saturdays, I prepare a secret report on certain aspects of the same research for my industrial supporters. On Sundays, if I have any time to spare, I probably ought to pray for my endangered soul.

Research scientists in organisations right across the spectrum not only share the same epistemic values: they are also being faced with the same challenges to their moral values. The latent contradictions between the traditional responses to these challenges thus become quite clear. The genuine ethical dilemmas that lie behind these contradictions can no longer be suppressed. The pure scientist's claim to 'objectivity' and 'impartiality' has to be squared with the fact that she is being 'sponsored' by a company or state agency with a manifest societal agenda. The applied scientist's plea that he is the mere servant of an impersonal corporation power has to be reconciled somehow with the fact that he is himself the entrepreneur that owns the corporation.

Let me make it quite clear that I would not expect the study of the social relations of science and technology to resolve these inconsistencies. Quite the contrary. Moral dilemmas are of the essence of the human condition. The function of ethical analysis is to make them apparent, and to strengthen the will to face and decide them according to ones best endeavours. A realistic account of the nature of modern technoscience as a social institution is only the first step in such an analysis – but also an absolutely essential step for the student entering this complex form of life.

Above all, however, I want students to realise that the question: "What do you think you are doing?" does not have a pat answer. It is no longer convincing to say "I am just producing knowledge that others might possibly use", or, alternatively, "I am just solving a technical problem assigned to me by our research manager". Moral values, like epistemic values, are neither absolute nor arbitrary. On the one hand, they cannot be deduced formally like geometric proofs from a few axiomatic doctrines: on the other hand, when they come into conflict it is morally irresponsible to leave the outcome to personal whims, cultural preferences or brute force.

The pedagogic style of our proposed ethical module should be that an ethical assessment of a situation, like a scientific assessment, depends on the whole context and is never to be considered incorrigible. The full answer to the question 'What do you think you are doing?' has to go beyond the supposed facts of the case and the various ethical precepts presumed to be at stake. It has to include an account of the particular grounds on which these facts and precepts might be considered well-founded, relevant and conducive to human welfare. That account can never be closed, but it is what determines the moral value of the actual behaviour of scientists in society.

8. Establishing technological values

And now, at last, I can redeem my half-promise to say something about bringing *technological* values into science education By this I do not, of course, mean just engineering efficiency or economic rationality. I mean the conjunction of epistemic and moral values across the boundary between science and society.

On the one hand, the pursuit of reliable knowledge is fundamentally a moral enterprise. Academic science has never been an entirely instrumental activity, where anything goes if it goes. It is driven by, and completely dependent on, personal norms of integrity, honesty, sincerity and trust that cannot plausibly be explained away as just enlightened self-interest. Its epistemic values are only as good as the moral imperatives that motivate and constraint scientists in their work. I sometimes set it as a thought experiment to imagine what sort of knowledge would be produced in a culture where lying was the principal mode of public discourse and not being found out was the only way to success. I suppose there never could be such a culture, but I can think of sub-cultures where systematic deceit is prevalent and am not surprised that they are scientifically barren.

On the other hand, epistemically valued propositions – scientific truths, if you will – have a moral value beyond the practical uses to which they may be applied. This is evident in the public interest and honour accorded to scientific discoveries and their makers. The ways in which people talk about Albert Einstein or Louis Pasteur, for example, are similar to the ways in which they talk about saints or spiritual leaders such as Mother Teresa or Mahatma Gandhi. In all such cases, of course, human realities are never as clean-cut and inspiring as the hagiographies proclaim. But dedication to scientific truth is considered as meritorious as comparable dedication to other human needs. Again, to describe a scientific or technological concept as 'technically sweet' indicates an aesthetic virtuosity almost equivalent to a moral virtue.

But there is a danger here, against which every scientist should be warned. The pursuit of valid, reliable knowledge is in many ways a calling of high ethical value. Truth, one says, is amongst the principal aspirations of humanity and the search for it one of our major moral enterprises. But it must not be raised to the supreme goal of human existence, predominant over all others. That is why the scientist who takes a job doing research on Napalm on the grounds that it is 'good chemistry' is almost as much a pervert as the medical researcher who experiments on patients without their informed consent. Doing 'good science' is not synonymous with being a good person.

It is well known, moreover, that moral values cannot be derived from epistemic values – that what 'ought' to be done cannot be deduced from what 'is' or 'could be'. In the final analysis, moral values must be seen as independent of, and superior to, unqualified epistemic values. In proposing a new module for science education, we introduce the Philosophy of Science and Ethics as distinct disciplines, neither of which implies the other. In a metascientific perspective, however, the living relationship between their respective themes should be the focal point on which these studies should converge.

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