Science versus engineering

SIR—Whereas you ask (*Nature* **326,** 737; 1987) why technology is so isolated from science, I prefer to wonder why science is so isolated from technology and what role both may have in the engineering to which you address your views. I have previously covered the issue in an article that fully[1] agrees with your differences in motivation and reward between scientists and technologists. One recalls Alvin Toffler's definition that technology was developed to meet one of two criteria: "Does it make a buck or a big bang?" For it is the commercial aspects that divorce the scientists from technology and its applications in engineering.

Most (electrical) engineers are not interested as such in descriptions of new semiconductor devices, laconic or not. It is the ability to get into economic and reliable production those devices that satisfy an identified need, and to incorporate these devices into products the customers want, that drives the engineer. Most new products use only existing technology and it is in that light one must place the work of engineers, technologists and scientists. A spectrum does exist from science and applied mathematics to engineering, but the research role as understood by the scientist (and too often the politician) is a small one in the successful operation of a strong, internationally competitive manufacturing or consulting engineering enterprise.

In Britain, as in Australia, the scientist is too divorced from commercial aspects of technology and at the same time does not appreciate the professional nature of engineering in which "design for profitable manufacture should be as much the focal point for engineers as the human body is to the medical profession"[2]. If external validation of the quality of graduate engineers is considered a mystique, so be it, but, as in medicine, the engineer has responsibilities for, and suffers the consequences of, engineering disasters in a way that the scientist does not. Understanding the difference between an academic science and a profession like engineering is a problem not yet resolved within the universities, our society and the scientific literature.

In engineering publications one sees the damage a scientific attitude to information and knowledge can do to industrial competitiveness. Technology, whether 'scientific' or empirical, in materials or processes or devices, is perhaps the major contribution to commercial success of the manufacturer, consulting engineer or whatever. It is a fatal fault to forget this by too generous publication or gift. It is said that Japan paid only $15,000 million towards the intellectual property it needed to achieve its current pre-eminence in engineering manufacture. The rest it obtained from a too-generous approach to detailed publication and only more recently from its own developments. To obtain details on advances in technology (perhaps in other than laconic style), I recommend ignoring *Applied Physics Letters* and looking at the 400,000 allegedly new inventions being protected by patent application each year.

That the editor of a scientific journal considers one to be venal, able to be bribed, to be sacrificing principles from sordid motives, if one patents and exploits intellectual property or technology, provides the best example yet that technology, let alone engineering, does not need science.

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Citation counts

SIR—Recent letters in *Nature*[1,2] on the use of citation counts as evaluative measures for allocating resources prompt us to comment on some of the data problems of citation analysis.

Citation analysis has been in existence for more than a quarter of a century; its literature now totals about 3,000 publications[3,4]. Yet its basic assumption — that scientists cite (reference) what influences them — has not been tested[5,6]. No-one has read a single paper and compared the information in it with items in its bibliography.

In a series of studies, we read papers in fields with which we are familiar and compared the information in the text with what was referenced. We found that only 30 per cent of the influence was cited[7]. We also found that citing is highly biased[8]. Some influences were always cited when used and others were never cited. About a third of the citations were to secondary sources, which means that a third of the credit that was given went to someone other than the originator of the idea or discovery[9]. Instead, they either do not cite at all or give positive and negative credit simultaneously. Brooks examined citer-motivation and found that 71 per cent of references were multiply motivated, a finding that undermines simple motivational models of citing[10,11].

We have recently completed a review of the data problems of citation analysis and find that only about half of them have been studied at all and that none of them has been studied exhaustively[12].

Add to these problems those discussed by others[2,6,10,13–17], and it becomes clear that it is premature to use citations for evaluative purposes. Before such a step can even be contemplated, we must know a great deal about citing behaviour, which requires that we study not only data problems and citer motivation but also the personal interactions of scientists by which information is exchanged and 'negotiated'[13,18].

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Turin shroud

SIR—I first wish to assure Denis Dutton (*Nature* **327,** 10; 1987) that all the institutions involved in the proposed radiocarbon dating of the Shroud of Turin are fully aware of the crucial need to ensure that the 'chain of evidence' remains unbroken. It was to meet this need that the British Museum accepted the invitation to act as 'guarantor' and independent observer.

The purpose of the meeting in Turin last autumn was to devise procedures for every step of the sampling and testing, procedures which could and would be monitored at every stage by the three certifying institutions, the British Museum, the Pontifical Academy of Sciences and the Archbishopric of Turin, to preclude any possibility of tampering with the samples.

These procedural steps have yet to be finally agreed by the Pontifical Academy of Sciences and the Archbishopric of Turin so I am not at liberty to divulge their details. But, I can reassure Dutton that should the proposed procedures be amended to introduce a possibility of tampering with the samples, the British Museum would decline to act as a certifying institution. Nor would the radiocarbon dating laboratories then necessarily be willing to participate in the project.

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