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Sigmatics- The Fusion of Science and Technology

PREAMBLE

For too long in the United Kingdom the pure sciences, particularly theoretical physics, have attracted unwarranted prestige, which has detracted status from engineering and technology, damaging the opportunities for industry to recruit suitable applicants. Both academic study and manufacturing industry are diminished when divorced from their roots and potential growing points. The ties between the pure sciences and industry are closer than many academics and industrialists allow. Action based on clearer recognition of this could bring a more immediate vitality to both science and industry.

The author of this article would like to go further; and argues for a new discipline encompassing both science and technology. Science and technology appear at either end of a single spectrum, yet may be sufficiently interlocked at the centre to justify treatment as a unity. The overlap tends to be masked by tradition, sophistication, size, ignorance and complexity. Within their intersection science and technology may share sufficient ideas, artifacts, historical origins and practical methods to gain strength from a single, or closely linked, treatment at school and University, and within industrial research. This could be reinforced by the introduction of a new word, sigmatics, to embrace both science and technology.

The powerful developed industrial countries may be sufficiently rich to survive inefficiency associated with fragmented science and technology. In developing countries, however, separation of science and technology is particularly harmful, providing burdens in a free economy from which these countries may never escape.

The shortage of scientists and technologists of high quality seems to have been with us for a long time, time enough one would have thought for the problem to have been overcome; and society often misuses the talents of those scientists and technologists it has. In the U.K. we still find many long-established firms believing that quality products which sold in the past will sell in the future and failing to employ enough scientists and technologists. These firms unwittingly insulate themselves, their products and workforces from the far-reaching changes of the last quarter of this century. Some developing countries, well aware of the advantages that skilled experts can bring, spend a disproportionate part of their national income endeavouring to produce enough scientists and technologists, only to see them either underemployed or joining the "brain-drain".

Could it be that our attitudes and priorities are wrong and so deeply entrenched that even the cataclysmic arrival of a potential solution would have little effect? Consider the output of scientists and technologists from U.K. schools. "Too few and too academic," was the view of the Dainton Report in 1968. Twenty years of school development projects emphasising the pure sciences, and the expensive, but separate, Project Technology have failed to alter the situation. The climate of mistaken thought, which puts the pure sciences on a higher plane, is just too intense. Perhaps this is to be expected when we find examples of priorities such as the British Government's Assessment of Performance Unit, set up to monitor school standards in English, mathematics and science, adding technology to their list, but only as an afterthought; and the Department of Education and Science's View of the Curriculum (1979) which recommends changes for science but does not mention technology and engineering. They have their blinkers on. It can be no surprise that some British schools still have curricula totally lacking any reference to technology. It is encouraging to note that, in the current debate in U.K. concerning national criteria for a single system of examining at the age of 16+, attempts are being made to broaden the scope of science teaching in schools. A Schools Council committee, in its recommendations for what science syllabuses should be designed to promote, includes:

> "the ability to formulate possible solutions to simple real-life problems through the

application of scientific principles";

"the awareness of the potential of science for the benefit and for the detriment of society and the environment";

"an appreciation of the significance of biology within society in connection with health, the provision of food, the management of resources and the maintenance of a pollution-free environment";

"an awareness of the economic and environmental implications of chemistry";

"an appreciation of the impact of physics upon society in connection with the production and use of energy and applications within technology".

This may be the start of a welcome trend to bring more worldly relevance into science syllabuses; but is it enough? The recommendations do not include the impact of man and society on science; and the wording implies that science should be taught first and its effect on society afterwards. Should they not be brought closer together? The U.K. is not alone in its neglect of science and society links. The Ordinary level science syllabuses and examination in Singapore schools remain remarkably "pure".

The Finniston Report of 1980 called for change; and a signpost to a desirable direction for that change may come from an increasing number of writers appraising developments within industry when they refer to science-and-technology or science-technology, implying that science and technology are joined in some way. They have wanted to avoid undue emphasis on one aspect of the combination to the neglect of the other. Within micro-electronics, for example, there seems to be no clear-cut distinction between developments which are scientific as opposed to those which are technological. Perhaps the time is ripe for a re-examination of the relationship between the natural sciences and technology.

Unfortunately many people in influential positions have views of the relationship between science and technology which are both simplistic and wrong. Take, for example, the committee of the Royal Society under the chairmanship of Sir Ieuan Maddock which published a pamphlet in connection with the United Nations Conference on Science and Technology for Development in 1978. They wrote:

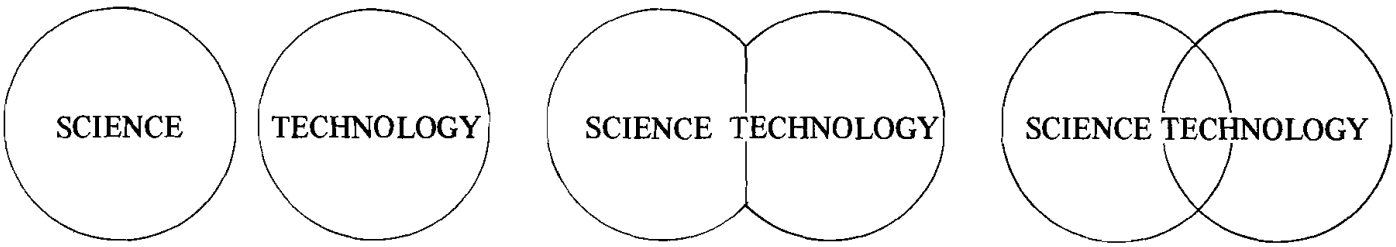
"There is a fundamental difference between science and technology. Science aims to provide, for its own sake, an understanding of the natural world."

"Technology applies the understanding of the natural world to practical problems and is a major factor in development."

Their view suggests a clear order of events: science first, technology after. It is the same sequence which is apparent in the extracts from the report of a U.K. Schools Council committee. However, the history of science is not so clear-cut; and many examples suggest the opposite. Thermodynamics did not precede the steam engine; Leonardo da Vinci did not distinguish between scientific and technical achievements; and many modern developments follow Leonardo's example. We must accept that the relationship between the sciences and technology is much more complicated than the Royal Society's committee supposes.

The origins of the words, science and technology, do not help much because what we now call scientific and technological practices certainly predate the invention of the terms and probably predate recorded history. Their relationship, although not necessarily made explicit at the time, has suffered various emphases, changes and separations throughout the ages and in different cultures. For example, the unified relationship in some present-day primitive societies which exhibit a highly developed and esteemed craft tradition linked to quasi-scientific and religious rituals differs widely from the clearer separation within Greek civilisation of 2000 years ago in which many scholars were ignorant of simple technical processes which had been relegated to the slave community. Although more recent than the introduction of the word science, the origins of the word technology are obscure. Technology suggests the science of techniques, and its use implies greater breadth than techniques. Clearly it is something more than a craft tradition. It must include some scientific account. Technology seeks scientific principles on which to base sound practice. It does not necessarily find those principles. Nevertheless, its practice implies reasoned design and planned construction insofar as that is possible in the light of contemporary knowledge.

If we attempt to represent the relationship between science and technology diagrammatically, then clearly separate and interface models will not do. The scientific content of technology demands an inter section.



SEPARATION **INTERFACE** **INTERSECTION**

Crafts form part of technology and not obviously of science. This could put them on the diagram within technology but outside the shared intersection with science. The craft tradition rests on evolution based on "trial and error" and apprenticeship rather than any application of explicit scientific principles. Successful modifications of artifacts become incorporated in the tradition; obvious mistakes are not repeated. Sound practice is passed on by imitation. Scientific principles would not be denied, but they are not essential to the craft. Crafts cut off from the intersection with science could exist on their own and in their own right; but if they wish to claim the title of technology for themselves, then it is essential that the link with science is maintained. It is the examination of craft-objects and their associated technical processes scientifically and critically which raised them to the level of technology. Of course, there are the artifacts resulting from the craft tradition which are picked up by a research worker and used in a scientific experiment, but this alone is hardly a strong enough link to warrant calling them technological objects.

What parallel with crafts is there with the part of science in the diagram drawn outside the intersection with technology? If such parts exist at all, can they exist separately as science or part of science without any links with technology? Consider statements like:

> "Laws of physics are invariant to translation from one inertial frame of reference to another."
>
> and
>
> "The different weights of one element which combine with a fixed weight of another element to form more than one compound are in simple multiple proportions to each other."

They have no apparent link with technology and so could lie outside the intersection. They enjoy the status of science by virtue of their place within the scientific theories which give them scientific meaning. (We will return to this point.) Now, it is the case that some theories do contain statements like the principle of conservation of energy which are obviously of direct relevance to technology; but this may be entirely fortuitous. These are statements which are part of the "understanding of the natural world" referred to in the Royal Society's definition of technology. A theory containing some statements relevant to technology and others not would fall across the line dividing science into two parts on the intersection diagram. So far in the argument the relationship between science and technology seems straight-forward and there can be a clear separation of the two notions; but the whole relationship is not so simple.

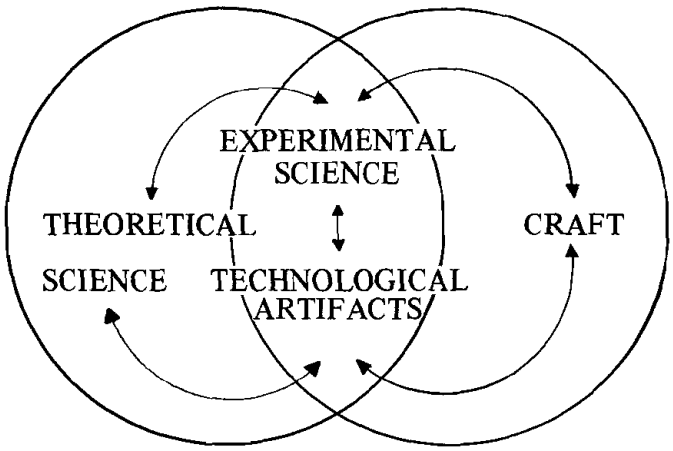
From what has been said to this point it would appear that a scientific statement stands in its own right whether or not it is used technologically to help solve some practical problem. It just has to be consistent with the theory of which it is a part. If this was all there was to say in the matter then science would indeed be independent of technology. But this is not the case. There is a way in which all scientific statements are linked to technology and it is more than use or mere proximity or historical accident. It is at the very core of science itself. It is now that we must return to the fact that statements enjoy the status of science by virtue of their place within the scientific theories which give them meaning. All scientific theories must, to some degree, accord with the natural world. This requires that all scientific theories are necessarily linked to the natural via observations and experiments; and from this link there is no escape. It follows that all the statements which form those theories are similarly linked. It is at this level that technical achievement enters the scene. Here it makes possible the realisation of the equipment essential to experimentation. Experiments which demand no apparatus are either extremely limited or trivial. Up to a point apparatus from the shelf or apparatus provided by a craft tradition may be sufficient; but this is not always so. The equipment may have come from a technological breakthrough. Often the necessary artifacts and know-how were not available at the time they were wanted by science so that scientific progress had to wait for technological development to provide

the means. This fundamental aspect of the relationship between science and technology falls totally within the intersection of them both.

It is the combination of the two processes which transcends them both: technology uses science; science uses technology. Together they form the science-technology cycle of development which is the very heart of the relationship between the two. For example: research in low temperature physics was not possible until technological development had provided ways of realising and maintaining very low temperatures; other technological developments were possible once research in low temperature physics had been done; and so on.

The trouble with our diagrammatic representation of the relationship between science and technology, even when the links have been added, is that it appears too static. The model shows the experiment and its theoretical ramifications feeding on its technology, and vice versa, but it does not fully bring out the cyclical nature of technology spawning science and science spawning technology. The dynamic aspect of progress through iterative cycles is missing. They may be historically irregular and erratic, sometimes discontinuous, but they are essential to any representation of science and technology. And in addition to progress, both planned and accidental, within the main stream of development, subsidiary cycles may result, leading to unexpected spin-offs: like non-stick frying pans from space research; and dislocation theory in crystallography from metal fatigue in aeroplanes.

Another weakness of the diagram is found in its hard edges. Accepting that the boundaries are as man-made as the subjects themselves, it is often impossible to draw a sharp line between scientific and technological developments. There is an interpenetration which the diagram does not show. For example, some vital processes from the theory and practice of engineering would be hard to place. If we are to retain the diagram at all, then, in addition to a third dimension for progress, we need to add fuzzy boundaries. To summarise: one must imagine, or get a computer to draw, an irregular, hazy and sometimes hairy triple helix springing out from the page.



LINKS WITHIN SCIENCE-TECHNOLOGY

There are dangers in getting the model wrong. Vast sums of money are spent by both industry and government to encourage development. Wrong views can lead to waste, or worse, to positive harm. As an example let us return to the Royal Society's pamphlet. The whole connection between science and technology at the level of experimentation is not stressed by them. They miss the importance of the experiment and its associated technology as a major growing point. But perhaps worst of all, they do not appreciate the important role of the science-technology cycle. They see the route from science to technology as a one-way track. In their pamphlet, prepared for the United Nations Conference on Science and Technology for Development, they call for licensed copying of technical processes for developing countries on the argument that those countries could never afford the necessary basic research. By doing so they condemn those countries to remain forever subservient, because their suggestion prevents the vital science and technology cycles from ever starting there. One can see a similar outcome in U.K. as recession bites deeply and firms cut research in an attempt to prevent bankrupcy. Undue polarisation of science and technology supported by unwise distribution of

funds weakens the links in the cycles of development so that the scientific, technological and industrial enterprise tends to stultify.

If the U.K. is harming itself and others by treating scientific and technological notions as totally separable, and if the links and common ground within science and technology are as important as this article suggests, then a single word to embrace and stress the unity of science and technology might help. What about *sigmatics?*

*Postcript: Sigmatics is made up from *sigma* to represent science and *tau* to represent technology. One could have combined them to form sigma-tau-ology, but that makes a clumsy word. Sigmatology is better. However, sigmatics (sigma-t-ics) provides a more compelling combination and is more pleasing to the ear.

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