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The rôle of the history and philosophy of technology in secondary education

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Introduction

If the history and philosophy of science is seen as a useful approach in secondary education, then the history and philosophy of technology has an equal claim. The history of technology has often been seen as the poor relation of the history of science, yet its study can not only support the learning of scientific principles, but also engage students in a debate about contemporary and often contested technological issues – from the 'information revolution' to climate change. From this point of view, technology is much more than applied science. Certainly, scientific principles are involved, but even in its 'purest' form, technology is more about designing artefacts and systems than understanding the natural world. This significant difference is reflected in the sort of models that technologists use for design. Even where the underlying mathematics of a technological model may be identical to a related scientific one (differential equations, Fourier transforms, for example), the way the models are elaborated and used within a technological or engineering culture is usually very different from the comparable scientific context.

In recent years the historiography of technology has been greatly influenced by "science and technology studies" (STS) and "social construction of technology" (SCOT) approaches, both of which can be used – albeit in a fairly elementary manner – to contextualise school studies in this area. As far as the philosophy of technology is concerned, it is certainly less well established as a discipline than the philosophy of science, and its major concerns – design, sustainability, tacit knowledge, and so on – are perhaps less easy to define than those of the philosophy of science – causality, scientific method, scientific revolutions, for example. Clearly, however, the two fields merge when considering a number of theoretical and practical issues, in particular the social context of science / technology.

Science and technology

Few would now treat technology as a linear consequence of fundamental science along the lines of

basic science → applied science → engineering → technology

Nevertheless, within most secondary schools, the science curriculum has very little to say about more complex technological phenomena. When it comes to the very minor presence of history and philosophy of science and technology, the emphasis is almost entirely on science. The history and philosophy of science as an academic discipline tends to concentrate on such issues as scientific method(s), causality, falsification, the mind-body problem, the scientific revolution, and so on. The history and philosophy of technology, on the other hand, is concerned with such matters as technological determinism versus the social construction of technology, issues of design and systems thinking, sustainability, tacit knowledge, practical ethics, and so on.

In recent decades the sociology, history and philosophy of science and technology have become very close, and some would even argue that it makes little sense to distinguish between them as separate disciplines. Major post-Kuhnian movements (Kuhn, 1962) have been Science and Technology Studies (STS), the Social Construction of Technology (SCOT); the Sociology of Scientific Knowledge (SSK); and Actor-Network Theory (ANT). This is not the place to discuss the origin and development of such movements, but major influences were the Edinburgh School from the 1970s onwards (Bloor, 1976); the Paris School (Callon, 1989; Latour, 1984); and academics at Maastricht and Twente (Bijker et al, 1987) and Bath (Collins & Pinch, 1993, 1998).

How can we use such ideas in the secondary classroom? Useful issues to be explored include:

- the complexity and contingency of technology – it is not simply applied science
- technological determinism versus social shaping (Smith & Marx, 1994)
- social, political, economic and legal aspects, as well as technical aspects
- is innovation and invention privileged over use and users? (Edgerton, 2006)

It is also profitable to link such teaching to current issues, for example: the contested history of ideas about climate change; the history of computing, ICT and the Internet (in order to explore the naïve deterministic notions promulgated by many politicians and much of the media); the ethics of social networking; the reasons for large-scale ICT systems failures; and many more.

Case studies can be extremely valuable, for example:

Case study 1 The development of the digital mobile phone
The European digital cell phone was promoted by the EEC (now the European Union) as a socio-technical good (Agar, 2003). It employed military technology for civilian use, and it was not obvious at the start of the GSM project that it would be technically feasible. It required the detailed development of a set of standards, and enormous investment by governments and telecommunications companies. The huge adoption of texting (SMS) was completely unexpected, and an example of users appropriating a new technology in a novel manner. Convergence (3G) with other ICT systems, particularly the Web, raised new challenges. Use in the developing world, particularly in Africa initially, turned the mobile phone into a more general and potentially liberating instrument for information and financial transactions.

Case Study 2 Household technologies
The development of household technologies for cooking, cleaning, food storage, child care, and so on, has much to say about socio-technological systems, gender issues, and market struggles between major manufacturers. A classic work is Cowan (1983), whose publisher's marketing states, with some justification:

> In this classic work of women's history (winner of the 1984 Dexter Prize from the Society for the History of Technology), Ruth Schwartz Cowan shows how and why modern women devote as much time to housework as did their colonial sisters. In lively and provocative prose, Cowan explains how the modern conveniences—washing machines, white flour, vacuums, commercial cotton—seemed at first to offer working-class women middle-class standards of comfort. Over time, however, it became clear that these gadgets and gizmos mainly replaced work previously conducted by men, children, and servants. Instead of living lives of leisure, middle-class women found themselves struggling to keep up with ever higher standards of cleanliness.

Such case studies offer a wealth of teaching opportunities within a variety of traditional school subjects.

Philosophy of technology in the classroom

In this section I shall give just three examples of questions that might be asked within many existing secondary curricula in order to foreground issues of the philosophy of technology.

Question 1 Is there such a thing as a feminist technology?

This is a fertile question for secondary school investigation and discussion. Let me quote one of the major thinkers in this area, Judy Waijcman:

> Feminist theories of technology have come a long way over the last quarter of a century. The intellectual exploration at the intersections of feminist scholarship and STS has enriched both fields immeasurably. While each has been characterised by diverse lines of argument over the last decades, the underlying continuities are all the more striking. Both fields foreground the way that people and artefacts co-evolve, reminding us that 'things could be otherwise', that technologies are not the inevitable result of the application of scientific and technological knowledge. For me, the distinguishing insight of feminist STS or technofeminism is that gender is integral to this sociotechnical process: that the materiality of technology affords or inhibits the doing of particular gender power relations. Women's identities, needs and priorities are configured together with digital technologies. For all the diversity of feminist voices, feminist scholars share a concern with the hierarchical divisions marking relations between men and women. Key to our analysis is the understanding that, while gender is embedded in technoscience, the relationship is not immutably fixed. While the design process is decisive, sociotechnical configurations exhibit different degrees of determination and contingency at different moments in their relationship. The capacity of women users to produce new, advantageous readings of artefacts is dependent on their broader economic and social circumstances. Such a perspective redefines the problem of the exclusion of groups of people from technological domains and activities. Technofeminism exposes how the concrete practices of design and innovation lead to the absence of specific users, such as women. While it is not always possible to specify in advance the characteristics of artefacts and information systems that would guarantee more inclusiveness, it is imperative that women are involved throughout the processes and practices of technological innovation. STS provides a theory of the constitutive power of tools, techniques and objects to

> materialise social, political and economics arrangements. Drawing more women into design—the configuration of artefacts—is not only an equal employment opportunity issue, but is also crucially about how the world we live in is shaped, and for whom. We live in a technological culture, a society that is constituted by science and technology, and so the politics of technology is integral to the renegotiation of gender power relations.
>
> (Waijcman, 2010)

Question 2 What does the term 'information revolution' mean?
As a starting point for a discussion of this issue I quote from one of my own recent publications:

> The historian and sociologist of science Steven Shapin opened his widely acclaimed book *The Scientific Revolution* with the words: 'There was no such thing as the Scientific Revolution, and this is a book about it'. He went on to write:
>
>> Some time ago […] historians announced the real existence of a coherent, cataclysmic, and climactic event that fundamentally and irrevocably changed what people knew about the natural world and how they secured knowledge of it. It was the moment at which the world was made modern, it was a Good Thing, and it happened sometime during the period from the late sixteenth to the early eighteenth century. It was, of course, the Scientific Revolution. (Shapin, 1996, p.1)
>
> Shapin's tongue-in-cheek opening words prompt a number of questions about the current 'information revolution':
>
> - is it a real, coherent, cataclysmic, and climactic event?
> - has it fundamentally and irrevocably changed our view of the world?
> - has it made the world *post*-modern?
> - when did it happen?
>
> (Bissell, 2012)

Question 3 "Do artefacts have politics?"
This question is the title of a famous paper by Langdon Winner, in which he postulated that the height of bridges on Long Island discriminated against blacks and poor people since buses could not use the route to the beach. The paper aroused heated discussion within the STS community, and a detailed rebuttal by Bernward Joerges ensued. An entertaining additional response was given by Woolgar and Cooper (1999), which includes references to the original papers. The controversy is still a useful starting point, at many academic levels, for a discussion of the complexities and difficulties of analysing socio-technical systems.

Engineering ethics

Most professional engineering bodies have codes of practice of professional ethics. These provide a useful benchmark against which to judge some current and recent technological ethical dilemmas. For example, the IEEE Code of Practise (abridged) exhorts and requires its members

- to accept responsibility in making decisions consistent with the safety, health and welfare of the public, to disclose factors that might endanger the public or the environment;
- to avoid real or perceived conflicts of interest whenever possible, and to disclose them when they do exist;
- to be honest and realistic in stating claims or estimates based on available data;
- to reject bribery in all its forms;
- to improve the understanding of technology;
- to maintain and improve our technical competence and to undertake technological tasks only if qualified;
- to seek, accept, and offer honest criticism of technical work, to acknowledge and correct errors, and to credit properly the contributions of others;
- to treat fairly all persons;
- to avoid injuring others, their property, reputation, or employment;
- to assist colleagues and co-workers in their professional development and to support them in following this code of ethics.

The following two case study outlines are based on actual events, and for more senior secondary school students provide an opportunity to explore these contested issues in the light of such codes of practice.

Case Study 3
An engineer becomes aware that a car is unsafe. The management decides it is cheaper to pay compensation to accident victims than to recall and / or redesign the vehicle. Should the engineer remain in the company and try to change the policy? Leave and say nothing? Blow the whistle and suffer the consequences?

Case Study 4
A group of engineering students working with NGOs and a western national organisation build a water clarification system in a developing country. The 'technicality' of the project is promoted both in the western home country and locally. On arrival on site it becomes clear that the design should be adapted for local conditions, and that much of the 'technology' is inappropriate or unnecessary. Nevertheless the system is installed, and an operator employed for it. Sometime later it seems that the system has rarely, if ever, been used. So, is it ethical to stress the advanced technology of a design, when local conditions require something else? Is it ethical to install a subsystem, and continue to pay an operator, when it is rarely, if ever used? How should 'high-tech' western engineers engage with local knowledge?

Philosophy of mathematics and modelling

There are great differences between mathematics as used in science and technology. School (and university) students tend to be taught a scientific / applied maths approach, which emphasises such techniques as solving equations, differential and integral calculus, matrix algebra, and so on. In contrast, technologists and engineers tend to use rules of thumb and diagrams – as well as computer simulation – and are more interested in general, rather than specific results: in particular, in generic approaches that give insight into design or analysis at the systems level. I have discussed this in some detail elsewhere (Bissell, 2012; and forthcoming). In the second of those two publications I remark by way of conclusion:

> This short chapter has aimed to present some of the major special characteristics of the way models are used in information engineering, in contrast to much of the literature on modelling in the natural sciences or economics. These characteristics include:
>
> 1. The primary aim of the modelling is for system synthesis or design, rather than analysis or explanation.
> 2. Many of the models are based on quite complicated mathematics, such as complex analysis and Fourier and Laplace transforms, and thus were not immediately accepted by practising engineers when they were introduced.
> 3. Practising engineers had to cope with considerable changes over the period outlined in this chapter, accepting increasingly more sophisticated models of electrical, electronic or control systems than they had been used to, and learning new languages with which to discuss their design processes.
> 4. The new models were converted into much simpler form for the use of engineers, particularly graphs and charts which, often isomorphic with the mathematical foundations of the techniques, were able to hide the complexities of the underlying models from practitioners.

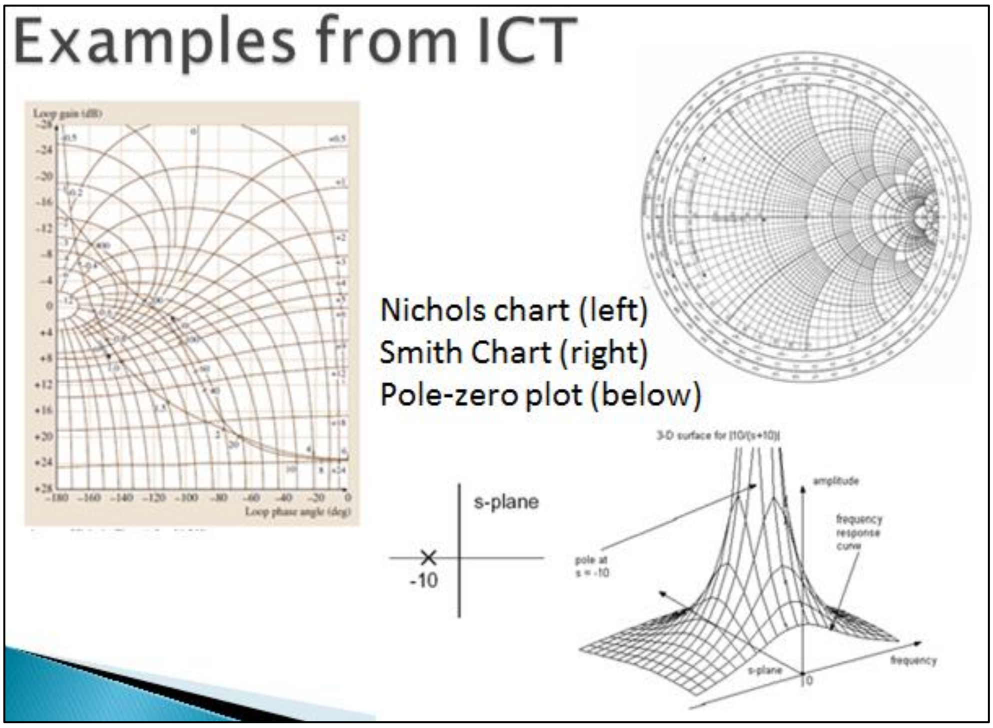

Figure 1 Some graphical ICT tools

Figure 1, taken from the conference presentation, illustrates three of these graphical modelling tools. These are all fairly advanced techniques, normally taught at undergraduate level, but the general principle also applies at secondary school level – namely, the contrast between formal mathematics, and the way engineering and technology practitioners have adopted and exploited such formalities in a way more appropriate to professional practice. The Nichols chart is a way of deriving a closed-loop frequency response from an open-loop model; the Smith chart is a tool for transmission line impedance matching eliminating the need for complex algebraic analysis; while pole-zero plots are a succinct isomorphic representation of a linear differential equation. All three are remarkable, user-friendly, visual representations of the sort of mathematics that many student and professional engineers find very difficult, and all are widely adopted in computer-aided design and simulation.

Constraints and conclusions

Different countries have very different secondary school curricula, some flexible, some highly prescribed. The study of the history and philosophy of technology, however, can fit into most systems, and easily form part of the teaching of, amongst other subjects, science, mathematics, history, social sciences and citizenship. Technology is not simply applied science, so the historical and philosophical aspects of technology can provide: a vehicle for teaching scientific, mathematical and technological principles; an opportunity to discuss a range of philosophical and ethical issues; a way to link social, economic and political problems to the relevant science and technology; and a way to demonstrate the complex, messy and contingent nature of socio-technical systems.

References

Agar, J. (2003, 2004), Constant Touch: a Global History of the Mobile Phone. Cambridge: Icon Books

Bijker, W. E., Hughes, T. P. and Pinch, T. J. (eds.) (1987), The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology. Cambridge, MA: MIT Press

Bissell, C. (2012), "Metatools for information engineering design", in: Bissell, Chris and Dillon, Chris (eds.), Ways of Thinking, Ways of Seeing: Mathematical and Other Modelling in Engineering and Technology. Automation, Collaboration and e-Services, 1. Berlin: Springer, pp. 71-94

Bissell, C. (forthcoming), "Electronics and Information Engineering: a new approach to modelling 1880-1950", in Pisano, R. and Capecchi, D. (eds), Physics, Astronomy and Engineering. A bridge between conceptual frameworks and technologies. Dordrecht: Springer

Bloor, D. (1976 / 1991), Knowledge and Social Imagery. London: Routledge / Chicago: University of Chicago Press

Callon, M. (ed) (1989), "La science et ses réseaux. Genèse et circulation des faits scientifiques" ("Science and its networks. Genesis and dissemination of scientific facts"). Découverte: Paris

Collins, H. and Pinch, T. (1993, 1998), The Golem. What you should know about Science. Cambridge: Cambridge University Press

Collins, H. and Pinch, T. (1998), The Golem at Large. What you should know about Technology. Cambridge: Cambridge University Press

Cowan, Ruth Schwarz (1983), More Work for Mother. New York: Basic Books

Edgerton, D. (2006), The Shock of the Old. London: Profile Books

Kuhn, T. S. (1962, 1970), The Structure of Scientific Revolutions. Chicago: University of Chicago Press

Latour, B. (1984), Science in Action. Milton Keynes: Open University Press / Cambridge, MA: Harvard University Press

Shapin, S. (1996), The Scientific Revolution, Chicago and London: University of Chicago Press

Smith, M. R. and Marx, L. (eds.) (1994), Does Technology Drive History? Cambridge MA: MIT Press

Waijcman, J. (2010), "Feminist theories of technology", Cambridge Journal of Economics, **34**:143–152

Woolgar, S. and Cooper, G. (1999), "Do Artefacts Have Ambivalence? Moses' Bridges, Winner's Bridges and other Urban Legends in S&TS"**,** Social Studies of Science **29**(3):433-449