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New connections: social studies of science and technology and studies of work

■ **Judy Wajcman**

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Debates about the role of information and communication technologies (ICTs) in transforming the economy and society are central to the sociology of work and employment. At their core, theories of the information society, post-Fordism and postmodernity, as well as more recent theories of globalization, the knowledge economy and the network society all contain claims about the dramatic effects of technological change (for example, Castells, 1996, 2001). Yet, to date, studies of work have rarely drawn on perspectives from the social studies of science and technology (STS).

Over the last two decades, STS has become established as a distinct academic field, with its own professional association (*Society for Social Studies of Science*), journals (*Science, Technology, & Human Values*; *Social Studies of Science*; *Science as Culture*), handbooks (Hackett et al., forthcoming; Jasanoff et al., 1995) and a book series (*Inside Technology*, MIT Press). While this burgeoning international literature is characterized by its interdisciplinarity, it emerged in large part from within the sociology of scientific knowledge. However, the sociology of work was also formative, particularly the labour process debates of the 1970s and 1980s. Since that time, the sociology of work, in common with sociology more generally, has failed to give due attention to the constitutive role of technology in society.

This article suggests that there is scope for more cross-fertilization between these two areas of social science. Up to now, studies of the relationship between technology and work have been limited by overly technicist theories about the impact of technology on skill and managerial control.¹ By contrast, STS emphasizes that, while it is important to understand the technical properties and material power of ICTs, the 'technical' and the 'social' are not separate spheres, but one and the same. Technologies not only change the nature and meaning of jobs and work activities, but they also reconfigure relationships between people and the spaces they occupy. The present essay begins by outlining the key

insights associated with STS. It then considers how a more nuanced analysis of the mutual shaping of technology and society might inform studies of the impact of ICTs on work and employment. The final section illustrates how treating technology as a culture helps to explain the gendered nature of jobs and the complex relationship between humans and machines. Indeed, there are signs that cyber-culture may be modifying the character of labour in the digital economy.

Social studies of technology

When STS developed in the 1970s it had a simple polemical purpose, to shake the stranglehold that a naive 'technological determinism' had on the dominant understanding of the intertwining of society and technology. This view of technology, as an external, autonomous force exerting an influence on society, narrowed the possibilities for democratic engagement with technology. While workers who opposed the introduction of new technology were routinely cast as Luddites, STS scholars emphasized that technologies could be redesigned to empower workers rather than dispense with them. Indeed, closely allied to this academic stream was enthusiasm for participatory design projects that involved workers in developing technologies.

STS, then, has its origins in a belief that the form and direction of technological innovation are amenable to social and political analysis. Crucially, this means rejecting the notion that technology is simply the product of rational technical imperatives; that a particular technology will triumph because it is intrinsically the best. Technical reasons are vitally important. But we need to ask why a technical reason was found to be compelling, when it could have been challenged, and what counts as technical superiority in specific circumstances. STS studies show that the generation and implementation of new technologies involve many choices between technical options. A range of social factors affect which of the technical options are selected. These choices shape technologies and, thereby, their social implications. In this way, technology is a sociotechnical product, patterned by the conditions of its creation and use.

There is now a considerable international literature, and a variety of approaches, to the social study of technology. The term 'constructivist' studies is often now used to include: the actor-network approach, the social-constructivist approach, and the systems approach to technology studies. Although there is much debate within STS about the differences between these approaches, there is actually a great deal of convergence between them and it could be argued that in many ways they represent a deepening of the social shaping approach to STS (MacKenzie and Wajcman, 1985, 1999).

So what is distinct about STS? For a start, this approach moves beyond a simple view of the politics of technology as a battle between directly opposing interests, such as capital and labour. Labour process theorists have traditionally concentrated on the role of class conflict in the social shaping of industrial machinery. In a similar vein, feminists demonstrated how, in a labour market

characterized by sex segregation, gender would leave its imprint on technology (Cockburn, 1983; Wajcman, 1991). Both these models of technological innovation assumed that the social interests embodied in technologies could be directly identified and straightforwardly designed into machines.

By contrast, an STS analysis of technical innovation does not treat social interests as pre-existing and a matter of overt dispute. Indeed, since the widespread adoption of actor–network theory, technology and society are no longer seen as separate spheres, influencing each other (Akrich, 1992; Callon, 1998; Latour, 1996). Rather, the metaphor of a ‘heterogeneous network’ conveys the view that technology and society are mutually constitutive: both are made of the same stuff – networks linking human beings and non-human entities. The technological, instead of being a sphere separate from society, is part of what makes large-scale society possible. So STS conceptualizes social interests, and even identities, as being co-produced with artefacts.

The actor–network theory concept of ‘script’, for example, captures how technological objects enable and constrain human relations as well as relationships between people and things (Akrich, 1992). In the design phase, technologists anticipate the interests, skills, motives, and behaviour of future users. Subsequently, these representations of users become materialized into the design of the new product. As a result, technologies contain a script (or scenario): they attribute and delegate specific competencies, actions, and responsibilities to users and technological artefacts. Being inscribed in this way, technology becomes an *actant* imposing its programme of action on its users. To be effective, programmes of action need to be inscribed not only into discrete devices, but also in aligned networks of technologies, humans and social institutions. However, this emphasis on how technological objects shape the ways in which people relate to things and to one another does not imply a technological determinist view of designers as active and users as passive. As we shall see below, STS emphasizes the *reciprocal* relationship between objects and subjects, designers and users.

Importantly, STS recognizes that even the criteria for judging whether a technology ‘works’ are contestable. For machines to work, they have to be accepted by relevant social groups, and this means constructing an environment in which favoured projects can be seen as viable (Law, 1987). In other words, technological outcomes are the result of engineering *social*, as well as *technical*, phenomena. Economists increasingly recognize that firms do not simply choose technologies that offer the maximum possible rate of profit. Notions of technological trajectory, path dependence and lock-in capture the mechanisms through which the evolution of a technology becomes more and more irreversible (a well-known example is the QWERTY keyboard [David, 1985]). The more technologies are adopted and their problems resolved, the better their performance and the greater their adoption. This clearly generates a powerful path-dependence over time, one that marginalizes competing or new technologies. Thus, it is not necessarily technical efficiency, but rather the contingencies

of socio-technical circumstances and the play of institutional interests that favour one technology over another (MacKenzie and Wajcman, 1999: 19–21).²

Contemporary technologies are increasingly systemic in character, foregrounding the utility of STS analyses of sociotechnical networks or systems. Although technological innovation crucially builds on previous technology, it does so not in the form of separate, isolated devices but as part of a whole, as part of a system. Railroads, electricity, utilities, telephone networks, the internet, and surveillance technologies are just a few of the technologies that take the form of networks of components distributed across time and space. A missile, for example, is itself part of an ordered system of component parts – warhead, guidance, control, propulsion – and also part of a wider system of launch equipment and command and control networks. The need for a part to integrate into the whole imposes major constraints on how that part should be designed. A technological system is never purely technical: its real-world functioning is simultaneously technical, economic, organizational, political, and even cultural. An STS approach involves thinking about technologies not as singular objects but as heterogeneous assemblages of socio-material practices.

Finally, STS scholars have challenged the linear model of innovation that represents it as an activity restricted to engineers and computer scientists in research and development. Long after artefacts leave the industrial laboratory, the process of technological design is still taking place. The construction of technologies is therefore seen as a moving, relational process achieved in daily social interactions. The implication is that the designers and promoters of a technology cannot completely predict or control its final uses. Rather, technological change is a thoroughly contingent and heterogeneous process. There is nothing inevitable about the ways technologies evolve. This point is particularly salient in relation to ICTs such as the mobile phone and the personal computer, as they are inherently more flexible than many older technologies. While the utility of a machine tool is limited, a mobile phone combines a phone, text messaging, e-mail, a web browser, a camera, a video recorder and, importantly, it is all these things at once. So the mobile phone is not just one thing – it is what people make of it and how it connects to existing social dynamics.

In recent years, STS scholars have increasingly focused on how users actively interact with artefacts to become agents of technological change. Media and cultural studies have long argued that technologies must be culturally appropriated to become functional: that material objects act as sources and markers of social relations and personal identities (Silverstone and Hirsch, 1992). While STS has tended to privilege the design process and the way this limits the flexibility of machines, there is now more recognition of the co-construction of users and technologies (Oudshoorn and Pinch, 2003). So, in a sense, these distinct literatures are attempting to rethink radically the conceptual divide between design and use, production and consumption.

Technology and skill

So what are some of the implications of STS for the study of work and employment? To begin with, the impact of technologies on work and skill is now understood to be always complex and uncertain. Consider for a moment the extensive labour process literature on the relationship between technology and worker's skills. The first wave of labour process theory argued that the capitalist imperative of profit and control led inexorably to deskilling. A classic example was Noble's (1984) study of the development of automatically controlled machine tools to control unionized, craft workers in post-war USA. A less popular view among neo-Marxists, but one that is perhaps more in tune with empirical evidence about changing education levels and the occupational distribution of the workforce, argues that the underlying trend line is towards upgrading in skill levels and high levels of trust (Adler, 2004). However, both these views tend towards a deterministic view of technological development as moving in a unidirectional trend. The solution to this quandary has been to argue that labour process theory can accommodate a contingency view of the impact of technology on the labour process (Smith and Thompson, 1999), a view more consistent with evidence of skill polarization.

An STS perspective would indeed argue that the politics of technology is about the power to shape definitions and mobilize resources under specific conditions for particular purposes. However, it stresses that even theoretically 'homogeneous' groups, such as capital and labour, have differing definitions of goals and of how to attain them. There can be broad agreement on a final objective, but the goals needed to meet it may be unclear and, thus, open to different definitions; and what they are is likely to emerge only over time. Labour process theorists have underestimated the complexity, uncertainty and contextual character of knowledge about technologies, including that which is regarded as purely 'technical'. This argument does not imply that technical knowledge is simply socially constructed and relative, or that choices are wholly open. To say that technology is socially shaped is not to say that all processes of social definition are equally effective. Rather, it is to stress that politics and negotiation are key processes through which technical possibilities are, or are not, put into practice.

Moreover, the analytical distinction between technical and social skills has underpinned much of the debate about managerial control and the machinery of manufacturing. Technical skills have been associated with the manipulation of things while social skills are related to dealing with people. In the context of work organizations, there is now increasing recognition that workers' social capital is as important an asset as technical skills to a firm's performance (Green, 2003). While the earlier socio-technical school (for example, Trist et al., 1963) depicted organizations as both technical and social systems, more recently evidence has emerged that social and technical skills are inseparable in contemporary work organizations. For example, Barley (1996) shows that the work of technicians in high-tech settings is neither blue-collar nor white-collar,

but combines intellectual and manual skills. Similarly, a recent study of technical salespeople in real-time computing in the US electronics industry concludes that, 'maintaining the distinction between social and technical skills will fail to address the shifting skill needs in contemporary work organisation' (Darr, 2004: 70).

STS has for a long time made parallel arguments that have become increasingly influential within the field of information systems, inspiring new collaborations between computer and social scientists (van House, 2004). A key publication was Suchman's (1987) *Plans and Situated Actions* that provided a critique of the individualistic and cognitive model of human behaviour employed by computer programmers and systems analysts. This model, according to Suchman, had not taken sufficient account of the 'situatedness' of social behaviour: that people's interaction with machines and with each other is highly dependent on the local context in which it takes place. Even the competent use of a supposedly simple machine such as a photocopier requires tacit knowledge and practical intelligence deployed in specific circumstances. In other words, interaction between people and machines implies mutual intelligibility, or shared understanding. Consequently, system designers now describe what goes on between computers and their users in terms of 'interaction', 'dialogue' and even 'conversation' (Hutchby, 2001).

Such an interactionist approach has informed a number of ethnographies of systems operation from air traffic control and the London Underground to news rooms and financial trading centres (Heath et al., 2000: 311). For example, in a 'socio-technology of arbitrage', Beunza and Stark (2004) argue persuasively that calculative practices are distributed across human and non-human agents and instruments in the trading room laboratory. These studies show how a variety of tools and technologies come into play in the course of particular activities, ranging from papers and documents through to computer systems and closed circuit television. The successive failure of some complex information systems, such as TAURUS designed for the London Stock Exchange, has particularly focused computer designers' minds on the social and situated character of technological procedures and practices (see Edwards and Wajcman, 2005: Chapter 7). Studies such as Vaughan's (1996), of the Challenger disaster, have similarly been influential in analyses of the limits of expert technical systems in large organizations.

More workplace studies are needed that consider how tools, artefacts and technologies feature in work practices and their accomplishment. This research has the potential to improve the design, evaluation and deployment of software, as well as giving due recognition to the innovative contribution of users. There are myriad examples, such as that open-source software like Linux, where a constant feedback loop between producers and users results in more efficient technologies (von Hippel, 2005). STS studies, then, provide a powerful argument for including 'knowledgable' users as participants in design and production processes in order to improve the real world functioning of ICTs.

Technology as culture

STS offers a distinctive method for examining the processes of technological design and innovation, highlighting the constitutive power of objects. As important, however, and the focus for the balance of this essay, is the conception of science and technology (or technoscience) as a culture. The cultural dimensions of technology have figured little in the sociology of work. Technology is generally understood in terms of physical objects and the technical knowledge necessary to make, repair and use them. A broader notion of technoscience as culture provides us with a more convincing explanation of how work is gendered and how identity is bound up with artefacts.

Let me illustrate this with the long-running debate about the impact of domestic technologies on unpaid housework. It has been common to argue that the ownership of domestic appliances reduces the time women spend on housework (Gershuny, 2000). This conclusion is obvious if we adopt a functionalist model of consumption, and a linear view of how time is spent. But this rather misses the point. When technologies enter the home, just like in the workplace, they change the nature and meaning of tasks, as well as creating new tasks. For example, domestic devices like ICTs have the capacity to permit multi-tasking and time-shifting, allowing for the rescheduling of tasks. Australian research, based on Time Use survey data, concludes that simply owning appliances rarely reduces housework, and tends to reinforce rather than undermine the sex-segregation of domestic tasks (Bittman et al., 2004).

How can it be that devices allegedly designed to save women domestic labour time either fail to save time or increase the time needed in some tasks? Part of the answer lies in the fact that the social and cultural construction of gender identity is still heavily implicated in the everyday practices of housework. To be feminine is to perform femininity, and the daily doing of housework continues to be pivotal to being a wife and mother. Domestic appliances thus enter a domain heavily signified in terms of traditional sex roles. Indeed, individuals demonstrate their gender identity in part through their daily use of technologies. An STS approach would argue that these artefacts are themselves inscribed with gendered meanings that shape their design and use.

Take the example of microwave ovens, a direct descendant of military radar technology, developed for food preparation in US navy submarines. When manufacturers first turned their eyes to the domestic market, they conceived of the microwave as a device to reheat prepared food for use by men, especially single men. As a result, it was marketed as a 'brown good' and sold next to hi-fi equipment, televisions, and video recorders – goods for leisure and entertainment. This attempt to frame demand was unsuccessful and subsequently both the product and the consumer were reconstituted as a 'white good' for housewives who still want to cook (Cockburn and Ormrod, 1993). Thus, even the microwave's colour reflects a gendered conception of household functions and, consequently, a gendered conception of potential purchasers and users – those concerned with domestic work. The finished form of the

microwave meant that the microwave literally shifted its place in the department store. It now sits alongside washing machines, fridges and freezers as a humdrum domestic appliance.

Feminist STS, or technofeminism, suggests that machines arrive in the household already imprinted with 'gender scripts' or agendas defining their appropriate operators (Oudshoorn et al., 2004; Wajcman, 2004). As technological innovation requires a renegotiation of gender relations and the articulation and performance of gender identities, these concepts capture the work involved in inscribing representations of masculinities and feminisms in technologies. They thus help explain why specific groups of people, in this case men and women, are invited or inhibited from technological domains and activities. In other words, such an analysis draws attention to the power of objects to impose programmes of action on its users. The emphasis then shifts from the deficiencies of users to the design of technologies. This fascination with the materiality of objects, and how ideas and identities can be expressed and experienced through artefacts, is a defining feature of STS.

The gendering of domestic technology is mirrored in the cultural construction of workplace technology. Sociologists of gender and work have long argued that this culture is a key factor in women's under-representation in scientific and technological pursuits (Cockburn, 1983; Oldenziel, 1999). Historians of technology reveal that its identification with masculinity is relatively recent, emerging with the formation of the engineering profession in the late 19th century. As a result, muscles, skill, strength, dexterity, rationality and labour time became the preserve of men and important power resources. While the masculine subject was enrolled into this sociotechnical network, standard versions of femininity were simultaneously excluded. This, together with male craft workers' traditional monopoly of industrial machinery, cemented the gendered definition of technical expertise still familiar today. Indeed, the tight connection between gender identities inscribed on the body and the emerging networks accounts for their durability.

Notwithstanding the recurring rhetoric about women's opportunities in the new knowledge economy, men continue to dominate technical work. For example, the proportion of women in the information technology, electronics and communications sector in the UK, USA, and much of Europe is low and has even declined by around 10 percent in the USA over the last decade (U.S. National Science Foundation, 2004; Millar and Jagger, 2001). In the cultural process of defining information technology, how it should be used and what the necessary skills are, or in other words what 'counts' as valuable knowledge and expertise, gender still functions as a cultural category in 'sorting things out' (Lie, 2003). In this process of negotiating boundaries, gender is a marker that still functions to sort out high-tech from low-tech or no-tech. Gender is thus constitutive for what is recognized as technology, and gendered identities and discourses are produced simultaneously with technologies. The fact that technology, culture and gender relations are so interwoven helps to explain why this link has proved so durable.

In sum, technofeminism characterizes the relationship between gender and technology as one of mutual shaping, in which technology is both a source and a consequence of gender relations (Wajcman, 2004). In other words, gender relations can be thought of as materialized in technology, and masculinity and femininity in turn acquire their meaning and character through their enrolment and embeddedness in working machines. As Haraway (1997) expresses it, the categories of gender, race and class should not be thought of as existing independently of technoscience, but rather as constituted in its practices. Such an approach shares the STS conception of technology as a sociotechnical network, and recognizes the need to integrate the material, discursive and social elements of technoscientific practice. This emphasizes that the process of technological change is integral to the renegotiation of gender power relations. It follows that women's emancipation at home and at work requires transforming the gender–technology relationship to enhance women's appropriation of tools and technical expertise.

The evidence is overwhelming that, while women have been systematically marginalized from IT expertise at work, a male subculture has developed around a special affinity with computers. I have written elsewhere about archetypal masculine cultures such as engineering, where mastery over technology is a source of both pleasure and power for the predominantly male profession (Wajcman, 1991). This resonates with today's dominant image of IT work, the young, white, male 'nerds' or 'hackers' who enjoy working 16-hour days. The 'cyber-brat pack' for the new millennium – those wealthy and entrepreneurial young guns of the internet – consists almost entirely of men. The masculine workplace culture of passionate virtuosity, typified by the hacker-style work, epitomizes a world of mastery, individualism, and nonsensuality. Being in an intimate relationship with a computer, is both a substitute for, and refuge from, the much more uncertain and complex relationships that characterize social life. Writers such as Castells (2001), who eulogize the counterculture hacker origins of Internet, fail to notice that the culture of computing is predominantly male.

In recent years, the sociology of work has been increasingly interested in how identity is formed at work. Computers occupy a special place in this, existing as they do on the border between the inanimate and the living, an extension of the self and part of the external world. Their special place betwixt and between traditional categories is part of what makes them compelling and evocative. They can no longer be viewed as tools, but rather as 'relational artifacts', as subjects in their own right (Turkle, 2005: 289). A consequence of this psychological entwinement with computers is that the digital revolution feeds off and profits hugely from free labour.

While the value of women's domestic labour is now widely recognized, another form of free labour, this time predominantly male, has remained largely invisible. According to Terranova (2000: 33), free cultural and technical labour drives innovation on the internet and is a structural feature of the digital economy: '[s]imultaneously voluntarily given and unwaged, enjoyed and exploited,

free labor on the Net includes the activity of building Web sites, modifying software packages, reading and participating in mailing lists, and building virtual spaces on MUDs and MOOs [multi-user text-based virtual environments accessible via the internet]'. The audience capable of writing software for personal computers, including software that is internet-aware, is massive and varied. According to one estimate, there are 18 million amateur programmers worldwide, or about three times the number of professional programmers (Lohr, 2004). For example, as I write, approximately 10,000 volunteers around the world are testing the latest version of computer software, the new Vista platform, for Microsoft. The unaccredited members of this net community are motivated by a desire for affective and pleasurable cultural production, their only reward being the social status that comes with being at the frontiers of innovation.

We do not usually recognize such activities as work, yet this free labour is a widespread activity throughout late capitalist societies. Indeed, the extraordinary pace and generative quality of innovation in information technology is largely the result of such labour, which is at one and the same time, production and consumption, work and cultural expression. Drawing on the Italian Autonomists concept of the 'social factory', Terranova (2000) argues that work processes have now shifted from the factory to society, setting in motion a continuous production of value that is completely immanent to the flows of the network society at large. Such activities fall outside Marx's concept of 'abstract labour' and signal a new mechanism for the extraction of value. Certainly, they raise still largely unexplored questions about the nature of work in the digital economy.

Conclusion

This commentary has attempted to capture some of the rich and exciting possibilities for a more fruitful dialogue between the social studies of technology and the sociology of work. In particular, an STS approach sheds new light on the relations between work and the processes of technological innovation and adoption. In showing how technologies both reflect and shape prevailing patterns of power, STS keeps a sharp focus on the significance of technical design, as well as on work and consumption. Importantly, it departs from much technicist thinking about the impact of technology on work that assumes that the character and capacity of artefacts is given, independent of human actors. Judgments about technical efficiency are themselves socially constituted, the result of engineering social, as well as technical, phenomena. Information technologies that enhance management control and extend the reach of surveillance also reconfigure modes of working and generate new social relationships. By conceiving of objects as actants that produce and materialize forms of action and ways of life, STS is especially attuned to the contradictions, contingencies, and nuances of technological development.

Rather than existing in a separate realm, technology is a constitutive part of social life, shaping and being shaped by culture. Directly as well as indirectly, it frames human experiences of space, time, communication, and consciousness. As I have argued earlier, gendered hierarchies and masculine and feminine subjectivities are created along with domestic and workplace technologies. The symbolic or discursive aspects of technology are critical in their effects and depend on human appropriation for their realization. Sociotechnical networks or assemblages are thus contingent and heterogeneous, necessitating continuous reproduction. Even when stabilized as material objects and subject to 'closure', the effects of technological change are indeterminate and negotiable. The uses people make of material artefacts routinely subvert the intended designs.

This will be ever more so as computing becomes ubiquitous, with digital devices increasingly embedded into everyday things and objects, part of our taken-for-granted environment. A focus on studying sociotechnical networks or systems, instead of singular technologies, will then be increasingly necessary for understanding work. ICTs are uniquely malleable and open to modification and interpretation by consumers. However, for all the hype about the network society, the internet does not automatically transform every user into an active producer, and every worker into a creative subject. The potential for empowerment offered by ICTs will largely be realized by those groups with technical knowledge who understand the workings of the machine. Acquisition of this know-how will become ever more critical.

STS provides a theory of the constitutive power of tools, techniques and objects to materialize social, political and economic arrangements. In doing so, it immediately extends conventional notions of workplace democracy to include parity of participation for both workers and consumers in the processes of technological innovation. Much current debate within STS is about precisely what architecture of accountability is appropriate for the governance of new technologies. Feminist STS has shown that the politics of technology is also gendered, thus requiring enhanced representation of women. I write this essay in the hope that an STS perspective will provide new insights for the field of work and employment as well as contributing to a renewal and reinvigoration of debates about the democratization of technology.

Notes

- 1 For an important exception, see Grint and Woolgar (1997) who argue for a more radical constructivism than the one represented here.
- 2 Interestingly, STS perspectives are being increasingly adopted in evolutionary economics and economic sociology (for example, the 2005 conference of the Society for the Advancement of Socio-Economics), as markets themselves are understood as embedded in social networks and even performative. See publications from the *Center on Organizational Innovation* (Columbia University), the *Centre for Research on Innovation and Competition* (University of

Manchester), and more generally the influence of Callon (1998), and MacKenzie and Millo (2003), on the sociology of finance.

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