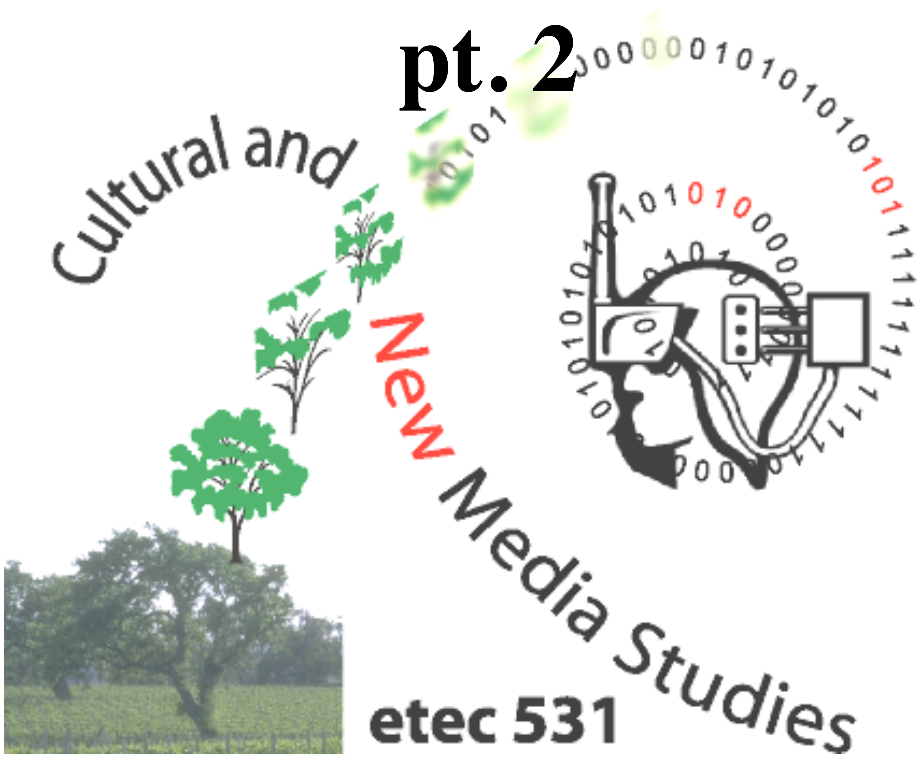
Primer for Defining and Theorizing Technology in Education, pt. 2



Dr. Stephen Petrina
Dr. Franc Feng
August 2008
University of British Columbia
Master of Educational Technology Program

Defining & Theorizing Technology, pt. 2

Excerpt from: Petrina, S. (2003). 'Two cultures' of technical courses and discourses: The case of computer-aided design. *International Journal of Technology and Design Education*, *13*(1), 47-73

And

Petrina, S., Feng, F. & Kim, J. (2008). Researching cognition and technology: How we learn across the lifespan. *International Journal of Technology and Design Education*. *17*(3), 1-22.

Sociotechnical Theo

Sociotechnical theories generally attend to relations between humans and their technologies, and more specifically to the deployment of technologies and corresponding dimensions of organization and use. In conventional sociotechnical theories of the 1950s these dimensions were defined in terms of an *interface* between human (social) and non-human (technological) *systems*. Generally, through **cybernetic and systems theory**, a language and model of feedback, control mechanisms and design were developed to capture human and machine behaviour. Original cybernetic notions were quickly moved from narrow, micro concerns with behaviours to account for macro cultural and organizational climates within which technologies were deployed. Primary interests centred on relationships among components in a dynamic system, rather than components themselves. Here, the behaviour, goal or state of a particular system is dependent on cultural, social and technical *components* being 'directively correlated'. *Coproducers* of outcomes or states, these components have distinctive characteristics that must necessarily be respected or *variance* (unprogrammed events) is a result. *Complements* among each of the components are realized and the probability of variance is reduced, only when *compatibility* of components is respected. Making certain that components interact harmoniously requires that characteristics are respected and correlated in both initial *design* and in progressive *use* (Cherns, 1976; Grint & Woolgar, 1997, pp. 14-18; Pasmore & Sherwood, 1978; Trist, 1959/1978, 1981, p. 37). The aim was the 'joint optimisation of the technical and the social systems' of industry and the military (Herbst, 1974, p. 4). This required a knowledge of the 'way machines and technical systems behave and of the way people and groups behave' (Cherns, 1976, p. 784).

Inasmuch as sociotechnical theories attend to human-machine relations they are founded on the work of 19th century theorists such as **Karl Marx** and **Max Weber**. Marx theorized that machine systems for production were designed so that labour was a mere appendage to capitalist industries. Labourers were coordinated with the movement of machine systems and subordinated to machine processes. Historically, technology and social systems were dialectically related: technology and society changed together. Avoiding a priority problem, Marx argued that technology combined with labour relations to act as a determinant force. What Marx did for industry and technology, Weber did for bureaucracy and rationality. Here, rationality and technology are determinants of the character of social relations and institutions. Critical theorists expanded on Marx's and Weber's theories of alienation, capital, labour, production and rationality (Feenberg, 1991; Leiss, 1990; Marcuse; 1964; Noble, 1984). Marcuse and the **Frankfurt School** may have been uneasy with the way that Fromm (1955) integrated **Freud with Marx**, but their conclusions were similar: The organization of labour and technologies produce desires and determine social character, *and* bureaucracies and technologies are in opposition to individual self-actualisation. The superstructure (character, institutions, norms) of a society is reducible and separate from the base (economics, technology). Other theorists of the 1950s argued that technologies do not determine human nature, relations or institutions; rather there are cultural, ecological, psychological and social factors independent of technology.

This humanistic, non-determinist notion was clearly articulated within the **Tavistock Institute of Human Relations** beginning in the 1950s. At Tavistock, Eric Trist and colleagues theorized that tasks could be arranged to promote psychological and social processes conducive to efficient, harmonious and productive relations (Herbst, 1976, pp. 3-8; Rose, 1989, pp. 87-101; Trist, 1981). In turn, the technologies could be manipulated to respond to ways that humans used these technologies. Humans could be made to adjust to technologies and technologies made to adjust to humans. At Tavistock, Trist and colleagues focused on the production of harmonious conditions, whereas critical theorists focused on conflicts necessary to overcome inequities already rooted in conditions of production. Where Marx argued that technologies in their very nature were political, Tavistock theorists worked to politically neutralize technology. Through the 1950s and 1960s, sociotechnical theories at the Tavistock Institute were extended from concerns with the dynamics of affordances and interfaces to concerns with adjustments to contexts and systems (Pasmore and Sherwood, 1978).

In the 1950s and 1960s, French theorists **Jacques Ellul** (1962, 1964) and **Louis Althusser** (1963) repudiated the humanism expressed at Tavistock and that of existential Marxists who countered determinism by privileging human agency over technology. Unlike Tavistock theorists, Ellul refused to privilege humans over technology. For Ellul, humans had given themselves over to technology, or technique, and agency was forfeited in the bargain. Human nature was unrecognisable in its total integration into technological systems. While much less deterministic than Ellul, Althusser also rejected existential theories of human nature (e.g., the desire to be free from determinism is a human essence). In rejecting essences of either humans or technology, Althusser argued that relations between humans and technology are defined in practice. Neither culture nor humans were determined. Rather, in practice, the human and the cultural were 'overdetermined' (1963, pp. 170-186). Departing from Marx on this point, he argued that economy, humans, society and technology were constituted by the other. Humans and society are not determined by economy and technology, but neither are humans free to determine technology or their relations with technology. The overdetermination thesis leaves the determinism question open, but does not limit determinism to one force or another.

During the 1980s and 1990s, work in science and technology studies (STS) helped us to rethink conventional notions of sociotechnical systems or sociotechnology (Grint & Woolgar, 1997, pp. 6-38; Law, 1987). In what amounted to attempts to counter determinist notions of critical theorists and the interests of Tavistock theorists who saw technical systems as neutral and independent from other systems, contextualists took cues from Althusser and argued that varying contexts (e.g., economic, social, political) constitute the designs and uses of technologies (Bijker, Hughes & Pinch, 1986; Law, 1987). **Contextualism** underscores the idea that technology itself is overdetermined, as Althusser noted, and does not develop in a vacuum. The cultural, social and psychological factors that, generally prior to the early 1960s, were seen as either dependent on or independent of technical factors came to be seen as interdependent with technology. These approaches gave way to more interactive theories in which technologies constitute various contexts. Where Trist and colleagues fashioned sociotechnical systems in response to *given* or essential demands of specific technologies and organizations, interactionists such as Bijker (1995) problematised these givens. Representative of interactive theories are 'sociotechnical ensembles', which are viewed as collectives or systems of economic, political, social and technical elements (Bijker, 1995, p. 249; Hughes, 1986; Law, 1987). In contextualism, technologies shape contexts and contexts shape the technologies in return, more or less in tandem. In **interactionism**, technologies and other systems are shaped together, simultaneously. Contextualists and interactionists reason that technologies are neither as malleable as non-determinists argue nor are they as durable as determinists posit (Petrina, 1992; Smith and Marx, 1994). Where Tavistock theorists satisfied Snow's premise (i.e., separate economic, political and technological factors) and conclusion (limited interaction), contextualists and interactionists rejected Snow's conclusion. Yet rather than accepting contextualism or interactionism, which assume a division of cultures, the most recent STS theories contain a rejection of the very premise that inspired Snow's description of two cultures.

Contextualism and interactionism are theoretically yielding to notions of **actor-networks**, **hybrids** and **cyborgs**, which erase essentialist, predetermined notions of what counts as culture, nature, society and technology. These divisions between culture, nature and society are abstractions of outcomes of particular practices. The new theories remove any contingencies of technologies on context and remove inside (technology) versus outside (society) distinctions. Boundaries or 'contexts' that are natural, social or technical are seen as the outcome of a long process of modern practices, and often change. **Hybridity theories** turn a twist on the Frankfurt School's position that technology is antagonistic to human nature and reject humanism. Here, human-machine relations are never fully harmonious nor antagonistic. Drawing from theorists such as Althusser and Ellul, this notion is underwritten by a radical attention to practice. Hence, it is misleading to theoretically differentiate between what, in contextualism and interactionism, are separate economic, human, natural, technical systems and so on. Instead, these systems lose their boundary distinctions in collectives such as cyborgs and hybrids (Gray, 1995; Grint & Woolgar, 1987; Haraway, 1985, 1995, 1997; Latour, 1987, 1993, 1999). Sociotechnical theories, ranging from the harmonious cybernetic relations of Tavistock to the disharmonious cyborgs of Haraway, have the express intention, albeit through different politics, of countering the alienation and apathy that developed in association with notions of technological determinism.

Theorising Cognition in a New Age of Technology

Of course, researching cognition and technology introduces theoretical as well as empirical challenges. Of the 247 reports we reviewed in 2004, and the dozens reviewed since, only a handful utilize theoretical frameworks sophisticated enough to account for cognition *and* technology. A vast majority of the reports utilizing any discernable framework at all rely on one variant of constructivism or another, based on the premise that learners are active in the construction of knowledge. Constructivists studying how we learn technology generally rely on work of the MIT Media Lab (Harel & Papert, 1991; Kafai & Resnick, 1996; Papert, 1992). During the 1980s and 90s, the Media Lab group, including Seymour Papert and Sherry Turkle, exploited new technologies to investigate cognition, ushering learning theory research and constructivism into the digital age, albeit with significant criticisms (e.g., Pea & Kurland, 1987; Pea, 1987; Pea, Kurland & Hawkins, 1987). One critique of constructivists is that they cannot adequately account for social interaction (e.g., parents, peers, teachers) and cultural dynamics (e.g., class, gender, race, sexuality) (Davis & Sumara, 2002). More importantly for our purposes here, constructivists undertheorise technology as mere tools for learning— as instrumental to cognition rather than integral (Shaffer & Clinton, under review).

Cognitive science and neurocognition similarly reinforce a focus on individual processes (e.g., Bransford, Brown & Cocking, 2000; DeMiranda, 2004; DeMiranda & Folkestad, 2000). In the 1940s and 1950s, biological and technological models of mind converged, yielding an integration of biology, ecology and cybernetics in what became cognitive science. Cognitive scientists reconfigured connectionism to model thought processes on electronic computation and information processing, with artificial intelligence on one hand and neurocognition on the other. Yet, as Clark (1997, 2003) notes, the further one delves into the internal workings of the head, the more one is wedded to the individual as the unit of analysis, and the less one is able to account for the environment, and specifically for technology (Figure 1). The more one is invested in theories on the left side of Figure 1, the more instrumental one casts technology in the process of cognition. The challenge for researchers is to shift units of analysis to the collective and hybrid nature of cognition (i.e., the right side of Figure 1).

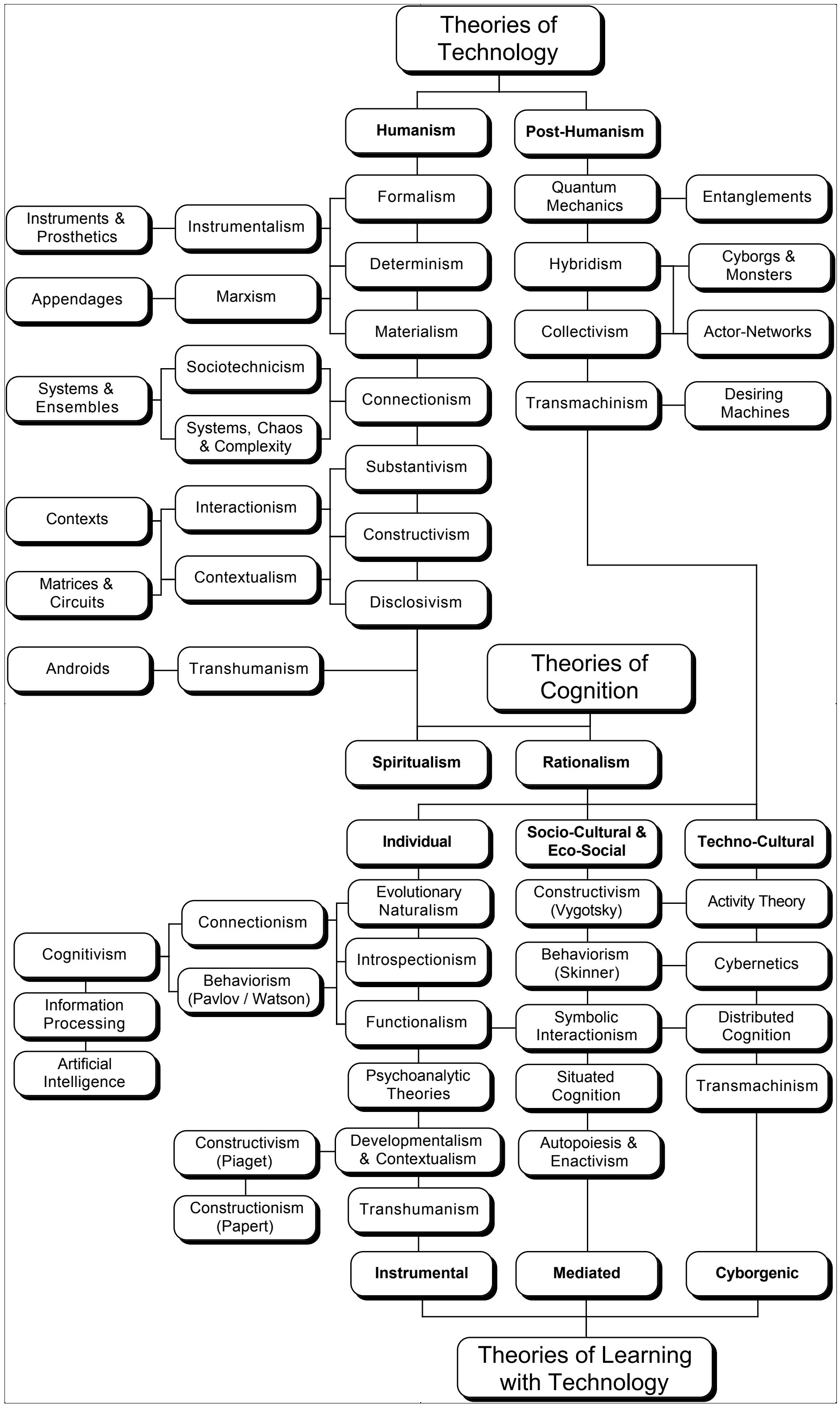


Figure 1. Mapping and theorising cognition and technology.

In effect, cognition is now inseparable from epistemology and ontology in a focus on social or postsocial knowledge and technology. Constructivism and situated cognition developed from the work of Piaget and Vygotsky and his colleagues, Leont'ev and Luria from the 1930s through the 1960s, and distributed cognition was theorised in the 1990s to account for technology in ways that previous theories of cognitive development could not. Similarly, from the 1950s through the 1970s, historians and sociologists of technology shifted approaches to sociotechnology, contextualism and social constructionism to explain human-technology interaction. In the 1980s, theorists of technology again shifted to actor-network theory, cultural studies, cyborgs, hybridity and postsocial relations with objects and the world (Petrina, 2003; Wajcman, 2002). Epistemologies of learning were effectively conflated with epistemologies of technological design and innovation. Indeed, a theory of distributed cognition is inseparable from a theory of cyborgs, hybridity and postsocial relations (Knorr Cetina, 1997; Latour, 1996a, 1996b).

A small percentage of research reports we reviewed reflect a turn toward sociocultural theories or specifically situated cognition and activity theory. In the popular *Situated Learning,* Jean Lave and Etienne Wenger shifted researchers' attention from individual minds (e.g., constructivism, neurocognition) to collective activity. This prompted researchers to cast learning in "apprenticeship" models and focus on the process of sharing (or distributing) cognitive responsibilities (e.g., Ahmed & Wallace, 2004; Chaiklin & Lave, 1993; Druin, 1999, 2002; Kittleson & Southerland, 2004; Stempfle & Badke-Schaub, 2002). Although Lave and Wenger recast cognition as collective activity, they continued to under-theorise technology in this process. Revisiting the premises of Soviet psychologists, such as Vygotsky, Luria and Leont'ev, activity theorists stressed the mediating role of artefacts in cognition to overcome the under-theorising of technology (e.g., Engeström. 2000, 2001; Verillon & Rabardel, 1995). The proper subject for cognition shifted from individual minds (constructivism) to collective activity (situated cognition) to activity systems.

Vygotsky, Luria and Leont'ev observed that activity was nearly always artefact-mediated (e.g., by knowledge, language, symbols, tools) and object-oriented (i.e., task driven). This was a breakthrough, as technologies ceased to be just raw material for cognitive amplification and development, or augmented learning. Activity or learning is always situated within an *activity system*. Situated cognition and activity theory have helped us rethink collective cognition and the central roles of technologies (all, not merely digital) in this process, and activity theorists have elaborated on how we might best theorise these roles (Chaiklin & Lave, 1993; Engeström, 2000, 2001; Nardi, 1996). Activity theory opens the door for theorising shifts from mediated to cyborgenic learning. For example, Downey (1998) demonstrated the degree to which learners are integrated into Computer-Aided Design (CAD) or human-computer interaction (HCI) systems (Petrina, 2003). Reluctant to give up control, or agency, students are nevertheless integrated into a CAD or HCI system. Cognition within these systems cannot be understood without fully accounting for technology or what Nardi and O'Day (1999) call "information ecologies".

This extension of mind and expansion of cognition is also notable in the work of anthropologist Gregory Bateson (1972), biologist Humberto Maturana and his student Francisco Varela, who shifted the unit of analysis to ecology, the mind of/in the world, and what they called cognitive systems. In 1972, Maturana and Varela coined the term "autopoiesis" to express the defining characteristic of all cognitive systems. Autopoiesis refers to a system's self-production (self-creation, self-learning) of components realizing its organization, or "biological autonomy". The defining property of living systems (notice the term is not "organism") is cognition, or the maintenance and preservation of relations and networks defining a living systems' unity. According to Maturana and Varela (1980), "*living systems are cognitive systems, and living as a process is a process of cognition*" (p. 13). Although partially derived from theories of technology (i.e., cybernetics, system dynamics, etc.), theorists of autopoiesis, enactivism and complexity, have not accounted for technology (e.g., Davis & Sumara, 2006; Davis, Sumara & Kieren, 1996; Davis, Sumara & Luce-Kapler, 2000; Sumara & Davis, 1997). Here, technologies are merely components or processes nested within, or incidental to other systems, generally for augmenting and embodying cognition (Brennan, Feng, Hall & Petrina, 2007; Winograd & Flores, 1986). Nonetheless, the cognitive agency of technologies within complex systems or information ecologies is crucial (Clark, 1997, 2003; Gardenfors & Johansson, 2005; Gorayska & Mey, 2002; Norman, 1993; Perkins, 1985; Perkins, et al., 2000; Saloman, 1993; Sternberg, 2005; van Oostendorp, 2003).

In distributed cognition, the unit of analysis shifts once again, to the system of person-in-interaction-with-technology. "The proper unit of analysis," says Hutchins (1995, p. 292), "is thus not bounded by the skin or the skull. It includes the socio-material environment of the person, and the boundaries of the system may shift during the course of activity." As Latour noted (1996b), Hutchins' conceptualization of distributed cognition offers the most empirically sophisticated account of both learning *and* technology in action (Flor & Hutchins, 1991; Hollan, Hutchins & Kirsh, 2000, pp. 177-179). Like Clark (1997, 2002), Haraway (1991), Ingold (2000) and Latour (1996a, 1996b, 1999), Hutchins dispenses with theories of cognition and learning that separate people from the technologies they use. As Hutchins (1995, p. 155) acknowledged, distributed cognition gives "new meaning for the term 'expert system'".

Clearly a good deal of expertise in the system is in the artifacts (both the external implements and the internal strategies)— not in the sense that artifacts are themselves intelligent or expert agents, or because the act of getting into coordination with the artifacts constitutes an expert performance by the person; rather, the system of person-in-interaction-with-technology exhibits expertise.

Learning, for Hutchins, "is adaptive reorganization in a complex system" (p. 289). Distributed cognition offers a powerful methodological and theoretical framework for researching cognition and technology, distilled into three questions (Hollan, Hutchins & Kirsh, 2000):

1. How are the cognitive processes and properties we normally associate with an individual mind distributed and implemented in a group of individuals?
2. How are these cognitive processes and properties distributed internally (attention, memory, executive function) and externally (artifacts, materials at hand, technologies)?
3. Distributed cognition "retains an interest in individual minds, but adds to that a focus on the material and social means of the construction of action and meaning". (pp. 176-179)

These questions guide a methodology of cognitive ethnography, or "event-centered ethnography" (pp. 179-183). This entails paying close attention to "not only what people know, but in how they go about using what they know to do." Hence, particular emphasis is placed on the recording of *cognitive processes* and events, within specific contexts, systems, or information ecologies.

References

Althusser, L. (1963). *For Marx*, trans. B. Brewster. London: Vintage Press,.

Bernard, E. (1987). A union course on new technologies. *Alternatives, 14*(3), 8-12.

Bijker, W. (1995). Sociohistorical technology studies. In S. Jasanoff, G. Markle, J. Peterson, & T. Pinch, Eds., *Handbook of science and technology studies* (pp. 229-256). London: SAGE.

Bijker, W., Hughes, T. P. & Pinch, T. (Eds.). (1987). *The social construction of technological systems: new directions in the sociology and history of technology*. Cambridge, MA: MIT Press.

Bijker, W. Law, J. (Eds.). (1992). *Shaping technology/Building society*. Cambridge, MA: MIT Press.

Bunge, M. (1999). Ethics and praxiology as technologies. *Techné, 4*(4), 1-3.

Cherns, A. (1976). The principles of sociotechnical design. *Human Relations*, *29*(8), 783-792.

Cherns, A. (1987). Principles of sociotechnical design revisited. *Human Relations*, *40*(3), 153-162.

Downey, G. L. (1992a). CAD/CAM saves the nation? *Knowledge and Society*, *9*, 143-168.

Downey, G. L. (1992b). Human agency in CAD/CAM technology. *Anthropology Today*, *8*(5), 2-6.

Downey, G. L. (1993). Steering technology development through computer-aided design. In Rip, A., Misa, T. & J. Schot (Eds.), *Managing technology in society: The approach of constructive technology assessment* (pp. 83-110). London: Wellington House.

Downey, G. L. (1998). *The machine in me: An anthropologist sits among computer engineers*. New York: Routledge.

Downey, G. L., Donovan, A. & Elliott, T. (1989). The invisible engineer: How engineering ceased to be a problem in science and technology studies. In L. Hargens, R. A. Jones & A.

Pickering, Eds., *Knowledge and society: Studies in the sociology of science past and present, volume 8* (pp. 189-216). Greenwich, CT: JAI Press.

Ellul, J.: 1962, 'The Technological Order,' *Technology and Culture* **3**(4), 394-421.

Ellul, J.: 1964, *The Technological Society*, trans. J. Wilkinson, Vintage Books, New York.

Feenberg, A. (1991). *Critical Theory of Technology*. New York: Oxford University Press.

Fromm, E. (1955). The Sane Society. Greenwich, CT: Fawcett Premier.

Gray, C. H. (1995). *The cyborg handbook*. New York: Routledge.

Grint, K. & Woolgar, S. (1997). *The machine at work*. Cambridge: Polity press.

Hacker, S. L. (1990). *Doing it the hard way: Investigations of gender and technology*. Boston: Unwin Hyman.

Haraway, D. (1985). A manifesto for cyborgs. *Socialist Review*, *15*(2), 65-107.

Haraway, D. (1995). Cyborgs and symbionts. In C. H. Gray, *The cyborg handbook* (pp. xii-xx). New York: Routledge.

Haraway, D. (1997). Modest *witness@second*_millennium.femaleman_meets_oncomouse. NY: Routledge.

Herbst, P. G. (1974). *Socio-technical design*. London: Tavistock Publications.

Hughes, T. P. (1986). The seemless web: Technology, science, etcetera, etcetera. *Social Studies of Science*, *16*(2), 281-292.
Latour, B. (1987). *Science in action*. Cambridge, MA: Harvard University Press.
Latour, B. (1993). *We have never been modern*. Cambridge, MA: Harvard University Press.
Latour, B. (1999). *Pandora's hope: Essays on the reality of science studies*. Cambridge, MA: Harvard University Press.
Law, J. (1987). The structure of sociotechnical engineering— a review of the new sociology of technology. *Sociological Review*, *35*(2), 405-424.
Leiss, W. (1990). *Under Technology's Thumb*. Montreal: McGill University Press.
Marcuse, H. (1941/1978). Some social implications of modern technology. In A. Arato & E. Gebhardt, Eds., *The essential Frankfurt School reader* (pp. 138-181). Oxford: Basil Blackwell.
Noble, D. (1984). *Forces of Production: A Social History of Industrial Automation.* New York: Oxford University Press.
Pasmore, W. & Sherwood, J. (Eds.). (1978). *Sociotechnical systems: A sourcebook*. LaJolla, CA: University Associates.
Petrina, S. (1990). An overview of technological forecasting and technology assessment.
Roland, A. (1992). Theories and models of technological change: Semantics and substance. *Science, Technology and Human Values, 17*(1), 79-100.
Rose, N. (1989). *Governing the soul: The shaping of the private self*. New York: Routledge.
Salzman, H. (1989). Computer-aided design: Limitations in automating design and drafting. *IEEE Transactions on Engineering Management*, *36*(3), 252-261.
Trist, E. (1959/1978). On socio-technical systems. In W. Pasmore & J. Sherwood, Eds., *Sociotechnical systems: A sourcebook* (pp. 43-57). LaJolla, CA: University Associates.
Trist, E. L. (1981). The sociotechnical perspective. In A. Van de Ven & W. F. Joyce (eds.), *Perspectives on organizational design and behavior* (pp. 19-69). New York: Wiley & Sons.
Vanderburg, W. H. (1992). Education for sustainability: A report card on engineering. *IEEE Technology and Society Magazine*, *11*(1), 26-31.
Vanderburg, W. H. & Khan, N. (1994). How well is engineering education incorporating societal issues? *Journal of Engineering Education*, *83*(4), 357-361.
Willoughby, K. (1990). *Technology Choice: A critique of the appropriate technology movement*. San Francisco: Westview.