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Two Cultures of Technical Courses and Discourses: The Case of Computer Aided Design

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ABSTRACT: Researchers in science and technology studies (STS) are in the process of dismantling the conventional human-machine and nature-society-technology boundaries solidified by C. P. Snow and generations of designers, engineers, researchers, scientists and teachers. Using the case of computer aided design (CAD), I argue that by combining the sociopolitical knowledge of STS with technical knowledge we can finally and forcefully bring an end to technical education. To make this argument, I draw on my experiences in teaching CAD in post-secondary institutions in design, engineering, and teacher education. Theories and practices are described to assist design and technology educators with the dilemma of addressing sociopolitical knowledge.

Keywords: Computer Aided Design (CAD), engineering education, technology education, science and technology studies (STS), technological literacy

In 1959, the English scientist C. P. Snow delivered a lecture at Cambridge University titled 'The Two Cultures and the Scientific Revolution'. Snow's concern was *not* with high and low, nor mass and elite culture. He argued that on one hand, there had developed a culture of engineering and science types – people with a logical, rational, quantitative worldview and a disdain for messiness, politics and subjectivity. The other culture that developed was made up of arts and humanities types – people who work qualitatively and merely tolerate, rather than celebrate, objectivity and precision. In one culture is a protection of humanity from politics, in the other a protection of humanity from rationality, science and technology. Both cultures consist of people aspiring to be 'design' and 'technology' educators. Design and technology educators *aspire* to fit into both cultures and to build bridges, often stretching their imaginations and senses to maintain relations in both.

On one hand, as Snow suggested, is a group whose interest is in technical conditions and objective means, reflecting that part of ourselves that necessarily works to reduce or even remove feelings and politics from our endeavours. On the other hand is a group whose endeavours are dependent on subjectivity, reflecting that part of us that empathises with personal desires and interpersonal politics. Ought we find norms in rationality and technology? Or ought we place priority on personal feelings and subjectivity? Accepting Snow's premise, this is indeed a troublesome tension. We know today that Snow's two-culture description is simplistic and fails to depict the fragmentation of literacies and selves (Petrina 2000a; Rapp 1986). Nonetheless, Snow's description does help us to confront educational practice. As aspiring design and technology educators we have been in a prime position to reintegrate or dismantle Snow's two cultures, but we have *not* done this. More often than not, we accept and reproduce a two-culture dichotomy. We may see ourselves as navigators across what we accept to be divides between humans and their technologies, but our courses and discourses say something different about us. But shouldn't we walk our talk? Ought not we be traitors to both sides and inject politics and subjectivity into technology and technology into humanity and morality (Latour 1999, p. 18)? What can we do to reintegrate, or dismantle, Snow's cultures to bring an end to technical education?

If conceptualisations of technical courses provide indices of change in practice and theory then a deliberate reintegration of sociopolitical with technical knowledge in a course amounts to a progressive change in curriculum. I argue that all of the technical courses that we teach, whether in schools or post-secondary institutions, should have as a deliberate goal a reintegration or a dismantling of Snow's two cultures. I argue for deliberately contextualising our technologies, and against the deferment of ethical-personal and sociopolitical content to other courses or the adding on of this content. Sociotechnical knowledge – the reintegration of sociopolitical with technical knowledge – spells the beginning of the end of technical education. This appeal is extended to a range of educators at all levels in engineering, design, graphics, technology and vocational education, most of whom are practicing what I call 'technical' education. On the level of practice, it is not worth splitting academic hairs between 'design', 'engineering', 'industrial', 'technical', 'technology' or 'vocational' education. In so far as each of these is practiced in very similar ways, each is a variation on technical education. The telling characteristic is the marked separation in courses and discourses of technical from sociopolitical knowledge.

Methodologically, this report is an expression of the new self-study practices in teacher education (Britzman 1990; Richardson 1994). Self-study research represents a 'deliberate attempt to collect data systematically that can offer insight into professional practice' (Clift, Veale, Johnson & Holland 1990, p. 104). In self-studies, these data are drawn from one's own practices. I draw on my experiences in teaching Computer-Aided Design (CAD) during the 1990s in post-secondary institutions in design, engineering, and teacher education. I also draw on a case study of the current preparation of technology teachers in CAD courses at the British Columbia Institute of Technology (BCIT). In my teaching and in this article, I choose to stick to sociopolitical issues that are concrete and within grasp; I stick to innovations with CAD in schools and workplaces. Or to phrase it differently, I choose to stick with small 't' and plural 'technologies' rather than big 'T' and singular 'Technology'. Since fiction, futurism and speculation on CAD are commonplace, but mostly inaccurate, I focus on empirical findings. I draw from ethnographic and sociological investigations of CAD in practice, and I summarize what sociotechnical research and theory have to say about CAD. In these investigations, CAD is *not* 'just a tool'. *What* do we really know about innovations with CAD in schools and workplaces and *how* do we know? What do we want our students to know? What does sociotechnical education, as opposed to technical education, entail? What do we envision as we profess to practice 'technology education', 'design and technology education' or 'technology studies education'?

IN CONVENTIONAL WISDOM, CAD IS 'JUST A TOOL'

Most teachers would conclude that CAD 'fits' nicely within the 'technical' curriculum in schools and in post-secondary institutions. But given customary patterns of teaching CAD the 'fit' may not be as nice as anticipated. One of our responsibilities in the change from industrial or technical education to design and technology education is the recontextualisation of our technologies – sociotechnology. In this case, time spent doing technical work in CAD laboratories ought to be used to shed light on the ethical-personal and sociopolitical dimensions of this work (Petrina 1998; Willoughby 1990, p. 267). Done right, this is *not* an easy task. Conventional wisdom in teaching CAD has tended to focus on questions that are technical in nature: 'How much and to what level shall we teach CAD?' Questions have been centred on software, hardware and the 2D versus 3D dilemma (i.e. two-dimensional drawings versus three-dimensional modeling). Like drafting in days gone by, courses and discourses in CAD remain technical in nature. Even during a time of recontextualisation, we are preoccupied with reproducing a division of two cultures (e.g. Anand, Haque & Anand 1993; Barr 1999; Becker 1991; Cartonnet 1999; Leach & Rajai 1995; Waggoner 1996).

For example, Becker (1991) conducted a study on CAD curricula through a 3-round Delphi survey to determine 'content and strategies for teaching CAD'. According to Becker, 'The panel of experts agreed that the traditional methods used in teaching drafting are very important and will be needed in teaching CAD. The panel also determined that CAD was similar to traditional content and consisted of basic drafting components. In addition, when teaching CAD the content should include a knowledge of CAD hardware and software' (p. 43). His panel of experts reached consensus on about 35 curricular statements that were technical in nature, such as: 'Orthographic projection should be taught using traditional drafting and CAD' (p. 42). Mild conclusions all in all, but Becker's study was ill conceived. Barr's (1999) survey yielded similar conclusions. It appears that the expertise he and Becker received was *not* what was needed. My first reaction was that here we are in the 1990s and educators are satisfied with technical education, albeit CAD instead of traditional drafting in this case. This neglect of sociotechnical knowledge is canonized in textbooks and the new CAD 'standards'. The best, new textbook for engineering graphics excludes sociopolitical knowledge in a comprehensive coverage of drafting and CAD (Bertoline, Wiebe, Miller & Nasman 1995). Likewise, the CADD National Occupational Skill Standards published in the United States (US) merely outline technical knowledge, with some generic academic and employability skills added at the end. Instead of reproducing two divided cultures by asking what technical knowledge in CAD or traditional drafting should be developed, we ought to be casting our nets a little wider.

In the institution where technology teachers in British Columbia (BC) are provided with the 'technical' phase of their program, the CAD courses are merely technical in content. There is a progression of knowledge from basic 2D AutoCAD commands to 3D modelling across three design, drafting and CAD courses – purely technical education. The instructors are working from an assumption that technical content is and ought to be taught in an isolated form. These courses at BCIT are not external to the teacher education program; they are a part of this program. We are teaching students in the secondary and post-secondary institutions that CAD is 'merely a tool' through which design, drafting and visualization skills can be refined. In the public schools in BC, CAD courses are great examples of the reproduction of technical education. While the CAD courses are nearly identical to drafting courses of another era, they are also identical to teacher education courses at BCIT in terms of content, pedagogy and projects. This is no coincidence. While we may be asking teachers to teach differently in schools, there currently exists a close match between the technical courses of post-secondary institutions and the technical courses taught in middle and high schools. At the same time that we have over-exaggerated technical content, our discourse on the ethical-personal and sociopolitical content of CAD has been attenuated and naive.

Through the use of CAD, students quickly engage with its possibilities. If asked about the possibilities of CAD, students tend to answer with the obvious: 'CAD systems help reduce time to redraw parts and to edit. Accuracy is enhanced, as fewer errors are committed. Crisp, clean, neat, accurate drawings can be produced. CAD produces and reproduces graphics more efficiently than by hand'. And then we teachers tend to step in and help our students out by explaining: 'CAD systems help link and integrate dimensions of the design and product life cycles. CAD can reduce design errors and make designing more effective and efficient through modelling and engineering analysis. This technology can configure design parameters and help ensure that designs are producible through integration with Computer-Aided Manufacturing (CAM). CAD/CAM can make designers and manufacturers more competitive and responsive to consumer and client needs'. And so on, we parrot the hype of CAD as articulated by CAD vendors and hopeful managers (Downey 1992a, 1998, pp. 82–143). We tell students that CAD has great potential for narrowing the 'gap' between design and production. We note that a global economy has restructured the way goods are produced, and we state with certainty that those companies that automate design and production will be flexible and ultimately competitive. We rarely do much more than this; rarely do we accurately explain the politically and technologically sophisticated workplaces where innovations with CAD occur.

We assure our students that CAD (or any technology) is 'just a tool', however misleading this assumption is. We do our part to reinforce a determinist discourse where CAD is a technical solution to technical and social problems. As we begin to attend to the sociopolitical content of CAD, as teachers, we quickly reach the limits of our own assumptions about this technology. We begin to realize how naive our innovation theories have been. Is maximizing profitability through hard and fast automation always a realistic goal for managers? Is there tension between this goal, a goal of an ecologically benign product, and worker goals? In this tension, something has to happen – something has to change – or does it? What happens as managers establish a scenario for full CAD productivity? What changes? It was when I confronted these types of questions, or when I reached my own limits, that I began to take seriously our mandate of dismantling two cultures by reintegrating sociopolitical and technical knowledge.

In 1985, I began teaching CAD to high school students and continued through 1987. From 1989 through 1995, I taught CAD to students in design, engineering, industrial technology, and teacher education programs at two Land Grant universities in the US. In 1990, I began to design 'sociotechnical' courses in CAD. Since that time, I have been teaching technology teachers in British Columbia to design sociotechnical as opposed to technical courses. In teaching CAD, I approached the issue of sociotechnical knowledge with a few assumptions. First, we can 'blow' the students' minds with Orwellian implications of 'Technology' and Toffleresque visions of 'Future Shock' in an 'Information Society'. Indeed, it was best to stick with organizational and social issues close at hand and related to CAD, preferably issues in the workplace. Second, fiction, futurism and speculation on CAD are commonplace and interesting, but research in this area is equally interesting. It was best to rely on researchers who were using sociological and ethnographic methods of inquiry to investigate and understand the interaction between CAD and people. I wanted 'real' studies of people working for and managing real companies; studies of people who were using CAD to innovate. Third, research could communicate some of the realities behind the problems, benefits and excitement of CAD. Empirical studies of CAD could provide students with a sense of how CAD was used in innovations, and how researchers designed and carried out their research. Fourth, I wanted my students to be *both* competent in CAD *and* knowledgeable of organizational practices in the workplace. In other words, I wanted the students to proficiently use CAD *and* to eventually help innovate for the reorganisation of workplaces, including schools. I wanted to teach students to be 'critically literate' – to be technologically sensible and politically astute (Petrina 1998, 2000a, 2000b). In effect, I spent more than a decade studying innovation with CAD in workplaces while figuring out possibilities for sociotechnical courses in design and technology education. Indeed, before encouraging our students to investigate or engage with sociotechnical questions, it is important that we have an understanding of sociotechnology.

SOCIOTECHNICAL THEORY

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 & 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.

CAD IN SOCIOTECHNICAL THEORY AND RESEARCH

How can sociotechnical theories and empirical research help us to understand innovations with CAD? First, sociotechnical theories challenge commonplace conceptions of technological determinism. In a deterministic view, technology, in our case CAD, is viewed as the primary force of changes in organizational and social aspects of a given company or industry. Sociotechnical theories empirically grounded in practice counter technological determinist models that see CAD as a primary agent of change. In many cases, managers implementing CAD have deterministic views of CAD realities, and expectations of the benefits to be achieved with CAD are invariably high. While they expect that automating with CAD will improve productivity, the innovation itself more often ends in little change or a decrease in productivity. Indeed, sociotechnical theories and empirical research lay to rest the claim that CAD is 'just a tool' (Webster 1991).

In sociotechnical theories, practices with technologies are contingent on a complex mix of interactive processes. The nature and success of practice will be defined as an outcome of these processes. The organizational culture of a company will certainly impinge on innovation with CAD, but so will CAD change this company's culture (Figure 1). Expectations and values that managers hold influence the CAD strategies that they adopt. The organizational culture for change as well as the nature of design processes used will shape practices with CAD. Structures and procedures established in the workplace, or methods of supervision will impinge on practices with CAD. The reverses of these conditions, where CAD practices impinge on design processes, markets, or supervision are also true. As is typically the case, with naïve, deterministic outlooks toward a particular technology a company innovating with CAD will witness results that are far from those intended.

Only those managers who eventually realize the importance of basic and complex, sociotechnical understandings are successful. Innovation in these managers' companies, which is marked by organizational and sociopolitical changes, will have a chance of providing improvement in productivity and personnel satisfaction. The interrelations between the various dimensions of innovation with CAD (Figure 1) cannot be underestimated if the

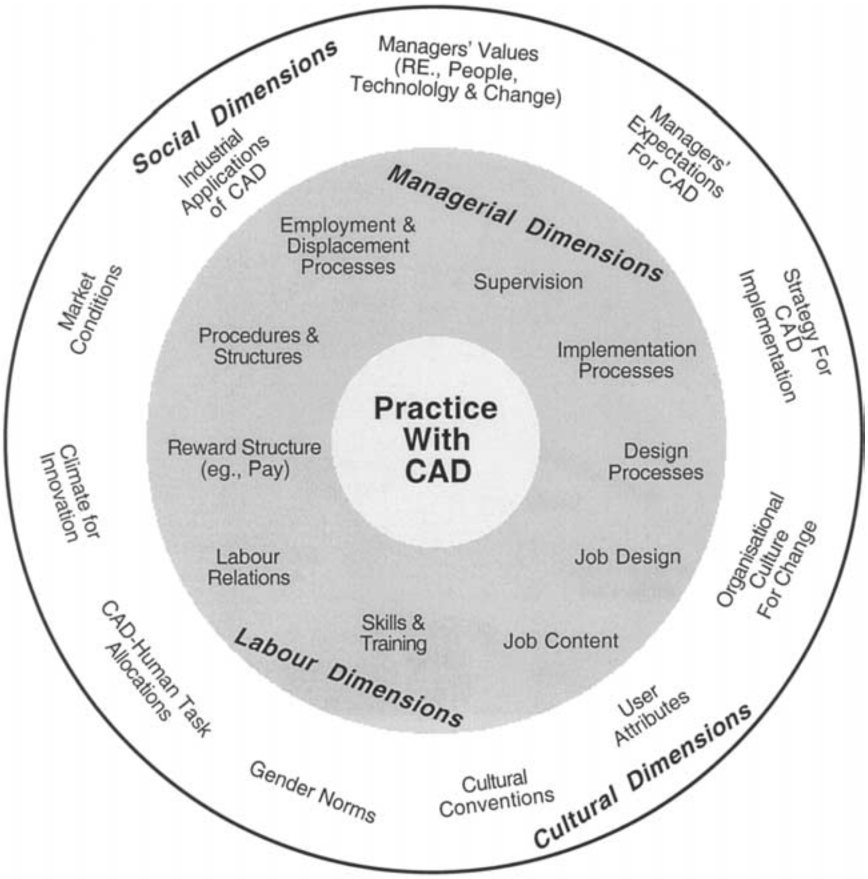

Figure 1. Sociotechnical theory suggests that innovation with technology can only be understood if interrelations among various dimensions are taken into consideration. In this case, practice with CAD is intricately tied to various workplaces practices (Majchrzak & Salzman 1989).

full potential of people working with technologies within workplaces is to be optimised. However, the optimisation of workplaces for people is often contradictory to the optimisation of workplaces for technology, and necessarily in conflict with productivity goals and competitiveness. Sociotechnical theories help to conceptualise a number of these types of problems:

- How, if at all, does the work and job content of designers and drafters change when CAD is introduced? What is speculated, what do we know?
- How have employment levels changed and what are the trends? Does CAD reduce the number of drafters needed, as predicted?
- Does CAD routinise work or eliminate drudgery? Is CAD nothing more than ‘button pushing?’

- Is CAD a 'Trojan Horse' with which Taylorism is introduced into intellectual work?
- Does CAD deskill? What are the skill and training realities of CAD?
- What role do labour relations play in the successful implementation of CAD?
- What are the critical factors for successful CAD implementation?

To be sure, researchers have been investigating a range of these questions concerning innovation with CAD (Darrah 1996; Majchrzak & Borys 1998). For example, Salzman (1989) provided a sense of how CAD interacts with the skills of drafters and employment trends. He set up two common and prevailing views and proceeded to knock them down. The first prevailing view he established was this: There will be an absolute decline in drafting employment, drafters will be displaced as CAD is adopted, and drafters will compose a relative decline in an occupational mix of drafters, engineers and technicians. He cited one prediction by economists who stated in 1986 that half of all drafters would be displaced through innovation with CAD by 1990 and, depending on economic growth, there may be 'no human drafters required by the year 2000' (p. 253). The second prevailing view was simply stated as follows: Deskilling and job fragmentation will occur through CAD. Salzman quoted Harley Shaiken, who said that 'CAD can become a vehicle to sever the designer even further from the realities of production; it may introduce new constraints into design, fragment work, allow skills to atrophy, and bring new isolation and stress to the job' (p. 253).

To address the first belief, Salzman used employment and CAD investment data to track trends in the automotive and aircraft industries during 1977–1986 (see also Vazzana & Bachman 1995). Through this, he concluded that from the late 1970s through the mid 1980s, 'investment in CAD systems in the aerospace and automobile industries rose dramatically . . . from under $50 million in 1977 in each industry to over $300 million in each industry in 1986, representing over 10,000 workplace purchases in each industry in 1986' (p. 255). This should have resulted in a decrease in the employment of drafters but the employment of drafters during this same period nearly doubled in the aircraft manufacturing industry, from 3600 drafters in 1977 to 7,100 in 1986, and nearly tripled in automobile manufacturing from 2,600 drafters in 1977 to 7400 in 1986. For Salzman, the data indicated that 'investment in CAD does not reduce absolute employment levels of drafters, nor does it reduce the demand for drafters relative to engineers and other professional technical workers' (p. 255).

To address the second belief that CAD automates complex skills and becomes button pushing, Salzman used field research and interview notes. Through this, he concluded 'in all the applications examined, CAD systems relieved the designer of the drudgery and less challenging aspects of the design process, increasing the preparation of time spent on the more challenging and more skilled work. It is the simplest, most routine tasks that become automated as the designer's job is transformed' (p. 259). As one designer who was interviewed put it: 'on a CAD system you approach it (the designing) differently. On the CAD system you collect all the data, then do all the designing. You let the computer hold the data for you, let the computer keep things straight, and you concentrate on your designing abilities' (p. 260). While this may come dangerously close to the notion that 'CAD is just a tool', Salzman carefully pointed out that through innovation with CAD, both job content and tasks changed for designers and drafters.

After reviewing reports such as Salzman's, some conclusions can be made. First, research lies to rest the technological determinist models that position CAD as a primary agent of change (see Figure 1). Second, managers implementing CAD appear to have inaccurate views of CAD realities, and expectations of the benefits to be achieved with CAD are invariably high. Managers often believe that an investment in CAD will be 'paid-back' by reduced personnel needs. Adler & Salzman (1989) show that these are unrealistic expectations. Managers often anticipate that CAD will promote integration across functions such as between design (CAD) and production (CAM). Collins & King (1988), Liker & Fleischer (1989) and Robertson & Allen (1992, 1993) suggested that CAD/CAM, or computer integrated manufacturing (CIM) systems alone will not help here. Well-informed organizational changes and a restructuring of workplace cultures are necessary. Third, expectations that managers have influence the CAD strategies that they adopt. Badham (1989), Brooks & Wells (1989), Lee (1989) and Robertson & Allen (1993) suggested that managers taking a technology-driven view toward innovation through CAD tend to adopt minimalist views toward organizational change. Without organizational restructuring advantages accrued through innovation will be minimal. Fourth, given the second and third conclusions, research suggests that companies using CAD have not achieved the full benefits that had been intended (Majchrzak & Borys 1998). Fifth, while the full benefits of CAD may not be achieved, CAD does allow for substantial savings. Adler (1989) and Manske & Wolf (1989) provided evidence that the number of labor hours to prepare or change a drawing substantially decreases with CAD. However, this may not translate directly into productivity increases. Forslin, Thulestedt & Andersson (1989) found that the time saved for modification was compensated for by an increase in people recommending changes. Sixth, the job design for designers does not drastically change with CAD, however the content of their job changes significantly. For example, 3D modeling requires an understanding of command structures for manipulating the model, conceptual synthesis of complex data points, ability to differentiate between design and software problems. Seventh, companies implementing CAD underestimate the amount and type of training needed for people involved. Badham (1989) found that this is a commonly overlooked reason that managers fail to realize their expectations of CAD. Supervisors are often assigned to CAD projects with no training; a result is that their judgement is questioned and their base of authority is eroded. Eighth, deskilling was not found in any organization implementing CAD. Deskilling did not occur and designers were not replaced by less-trained technicians (c.f. Hacker 1990). Ninth, full benefits from CAD are not achieved when CAD is regarded as a direct capital-for-labor investment. The full benefits of CAD are likely to be realized only when CAD is situated among other cultural and organizational changes made throughout the entire design process. Full benefits of CAD can become a reality only when sociotechnical, as opposed to technical solutions, to design problems are considered. And finally, while CAD may change the content and tasks of designers, the CAD profession is demographically similar to the drafting profession. Vazzana & Bachmann (1995) found that in the mid 1990s, 13% of the under age 34 and 6% of the over age 34 CAD workforce were women (Figure 2).

NARRATIVE OF RESISTANCE IN TEACHING CAD

I was taught traditional drafting at my high school and refined my technical drawing skills at California State University of Pennsylvania in the early 1980s. My first experiences with CAD were in the last year of my teacher-training program and in a one-week training workshop hosted by Intergraph in Pittsburgh during the winter of 1984. My experiences in teaching CAD date back to this same year, when I ordered two Macintosh 512 computers for the drafting course that I was teaching at Penn Cambria Senior High School in Pennsylvania. My students and I struggled along doing basic, two-dimensional (2D) drawings with MacDraw and MacDraft software applications. CAD was something the more senior and advanced students got to do after completing their board drafting assignments. In 1987, I began graduate studies at the University of Maryland with a teaching assist-

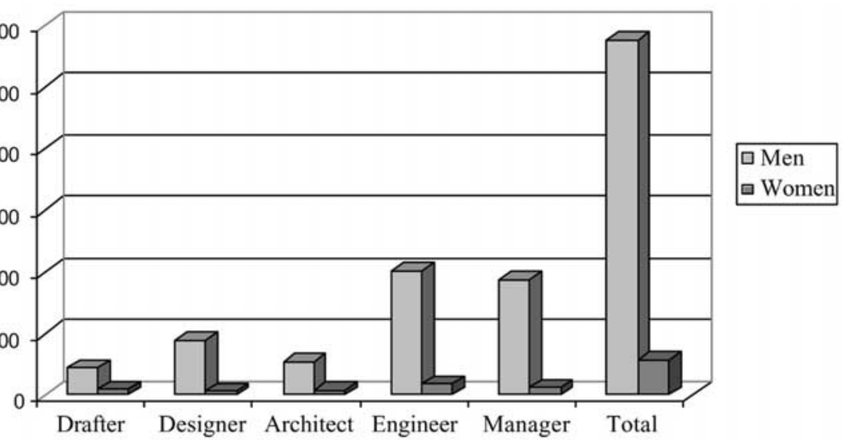

Figure 2. CAD industry by sex and profesion 1995 (n = 635).

antship and the charge of teaching beginning and advanced technical drawing courses to industrial technology and teacher education students. Our CAD capability amounted to a Tektronix station and AutoCAD loaded on a few IBM 8088 PCs. In 1988, my colleague (Ken Volk) centralized four of these PCs in a small, blueprint room and organized a CAD course, which was offered in subsequent years. When Ken was completing his studies in 1989 and 1990, the charge of teaching the CAD course became mine. By 1989 we were using AutoCAD Release 10 on IBM 286 PCs and in 1990 Auto CAD Release 11 on IBM 386 PCs in a laboratory of twenty machines. My first trials in teaching CAD to the industrial technology and teacher education students were in an advanced technical drawing course (EDIT 121) during the fall of 1988 (EDIT was merely the course prefix standing for Education, Department of Industrial Technology). The students were given a brief experience on CAD at the end of the term and a consensus formed that this must be the future. During that term I had a student who completed his drafting assignments on his PC using AutoCAD and pencil-traced the hard copies to get credit for the board drafting assignments! (He is now a designer for AutoDesk.) In 1989 I took the challenge of integrating drawing and CAD content, but my approach remained thoroughly technical (Outline 1). I taught advanced drafting on some days and introductory CAD on others and worked from the naïve position that CAD was ‘just a tool’. Through this experience with my students, we were able to resolve many of the difficulties of integrating two realms of technical knowledge. Given that one mould had been broken, it was not a great leap to integrate sociotechnical content the following term.

In the spring of 1990, I assumed responsibilities for teaching the CAD course (EDIT 488), and planned to integrate sociopolitical content along with the technical content of CAD. I adopted Dix and Riley’s *Discovering AutoCAD Rel. 10* which allowed us to move beyond mechanical part reproduction. The textbook however, did *not* deal with sociotechnical knowledge. I cobbled together an outline that I hoped would guide us through the sociotechnical field, but missed the mark (Outline 2). I was studying technology assessment and technological forecasting at the time and was interested in innovations occurring with CAD in offices and factories (Petrina 1990). I was unable to articulate what I wanted so we dealt with assessment, consumer choice, forecasting and issues related to innovation with CAD. I also learned a bit about the history of CAD and this helped me to highlight a range of issues regarding this technology (Chasen 1981). For one assignment the students reviewed a selected article from *Cadance, Catalyst, Consumer Reports*, or *PC Magazine*, wrote a summary and reported the summary to their peers. Another assignment involved a response to my overview of the sociotechnical content in CAD. The students subsequently reported on sociotechnical content of their choice. There was something missing and my lack of knowledge constrained our possibilities for attending to the sociotechnical content of CAD in an adequate way.

OUTLINE 1
Teaching CAD: Technical approach

Drafting	CAD
I. Terminology	I. Introduction
II. Detail/documentation drawings	A. Overview
A. Shape description	B. Components of CAD system
B. Figured dimensions	1. Hardware
C. Specifications	2. Software
D. Title block	C. DOS
E. Conventions	D. CAD user skills
III. Auxiliary views	E. Data storage
A. Primary	F. Data handling
B. Secondary	II. AutoCAD
IV. Assembly drawings	A. Main menu
A. Types	1. Drawing editor
B. Conventions	2. Configuration
V. Working drawings	3. Plotting
A. Details	B. Commands
B. Assembly	1. Drawing
C. Bill of Materials	2. Tool
D. Conventions	3. Edit
VI. Tolerances	4. Set-up
A. Production dims	5. Block and Attribute
B. Conventions	C. Prototype drawings
VII. Engineered fits	D. Simple geometric shapes
A. Types	1. Entity creation
B. Conventions	2. Plotting
VIII. Threaded fasteners	III. 2D drafting
A. Styles	A. Layers
B. Conventions	B. Dims
IX. Welds	C. Plotting with layers
A. Types	IV. 3D modeling
B. Conventions	A. Wireframe
X. Geometric Dimensioning and Tolerancing	B. Surfaces

Through my research in the summer of 1990 I found a collection of empirical research reports that attended to innovation with CAD in a variety of workplaces (Majchrzak & Salzman 1989). While I was naïve in my own sociotechnical knowledge of CAD, I found security in this research. For the fall term of 1990 I was able to take a significant step in making meaningful changes to the CAD course I was teaching (EDIT 231). After digesting the reports, I adopted most of these in a text of readings to serve as a complement to the Dix & Riley textbook. More importantly, I was able to rethink the course and take somewhat of a sociotechnical approach. This meant that our work with CAD in the laboratory would be coordinated with the sociotechnical issues with which we were dealing. If the task was to create a digital 2D detail drawing, then we asked questions about the changing nature of the tasks of drafters and engineers. We interrogated our own distributions of tasks and compared these with empirical

OUTLINE 2
Teaching CAD: social and technical approach

I. Introduction
  A. CAD
  B. Components of CAD systems
    1. Hardware
    2. Software
  C. Operating Systems
  D. CAD user skills
  E. Data storage
  F. Data handling
II. CAD system interface
  A. Main menu
    1. Drawing editor
    2. Configuration
    3. Plotting
  B. Commands
    1. Drawing
    2. Tool
    3. Edit
    4. Set-up
    5. Block and Attribute
  C. Prototype drawings
  D. Simple geometric shapes
    1. Entity creation
    2. Plotting
  E. 2D CAD
    1. Layers
    2. Dims
    3. Plotting with layers
III. Symbol libraries
  A. Access
  B. Organization
  C. Slides
IV. Databases
  A. Integration
  B. Dbase
V. 3D modeling
  A. Wireframes
  B. Extrusions
  C. Surfaces/Meshes
  D. Solids
VI. Design and Analysis

I. Implications of CAD
  A. Social
  B. Psychological
  C. Organizational
II. Education
  A. Motivation
  B. Potential
  C. Learning Strategies
III. History of CAD
  A. Invention
  B. Development
  C. Innovation
  D. Momentum
IV. Support for Users
  A. Journals
  B. User Groups
  C. Database services
V. Consumer Decision Making
  A. Criteria
  B. Information
VI. Organizational Decisions
  A. Market Trends
  B. Projected Opportunities
  C. Employment
  D. Managing Innovation
VII. Research
  A. State-of-the-Art
  B. Needs
VIII. Potential
  A. Productivity
  B. Overkill
IX. Creativity
X. Speculation
  A. 1995
  B. 2000

reports concerning these tasks. Students read and reported while I was able to coordinate our activities and work with what I was learning of the sociotechnical realities of CAD. For the term I developed a much more meaningful outline and vowed to address the technical and sociotechnical outlines concurrently (Outline 3). As is evident, there are stark differences between the right side of Outline 3 and the right side of Outline 2. The content presented in Outline 3 is much more directly related to what was

OUTLINE 3
Teaching CAD: Sociotechnical approach

I. Introduction
   A. CAD
   B. Components of CAD systems
      1. Hardware
      2. Software
   C. Operating Systems
   D. CAD user skills
   E. Data storage
   F. Data handling
II. CAD system interface
   A. Main menu
      1. Drawing editor
      2. Configuration
      3. Plotting
   B. Commands
      1. Drawing
      2. Tool
      3. Edit
      4. Set-up
      5. Block and Attribute
   C. Prototype drawings
   D. Simple geometric shapes
      1. Entity creation
      2. Plotting
   E. 2D CAD
      1. Layers
      2. Dims
      3. Plotting with layers
III. Symbol libraries
   A. Access
   B. Organization
   C. Slides
IV. Databases
   A. Integration
   B. Dbase
V. 3D modeling
   A. Wireframes
   B. Extrusions
   C. Surfaces/Meshes
   D. Solids
VI. Design and Analysis

I. Product and Service Life Cycles
   A. Designing, Engineering and Planning
      1. Data management
      2. CAD and DTP
      3. Parts Acquisition
      4. Concurrent Engineering Design
   B. Developing and Testing
   C. Producing
   D. Reintegrating, Reconceptualising, Recycling
   E. Constructive Technology Assessment
II. Economy, Workforce and Workplace
   A. Workplaces (Structure, Tasks, Culture)
   B. Market Trends and Forces
   C. Opportunities
      1. Worker Well-being
      2. Creativity and Productivity
      3. Labor and Management
III. Technology, People and Management
   A. Innovation in the Factory and Office
   B. Computers and Automation
   C. Managerial Innovation
   D. Organizational Structures
IV. Managerial, User and Consumer Decision Making
A. Forecasted Information
   B. Empirical Information
   C. Experience
   D. Continuing Education and Training
V. Sociotechnical Theory
   A. Sociotechnology and Workplaces
   B. History of CAD in Workplaces
   C. Sociology of CAD
   D. Psychology of CAD

relevant in the CAD laboratory and much more defined. Most of the students appreciated the approach and I was much happier with what it meant to reintegrate two realms of knowledge. I was able to see first-hand the significance of this approach.

My instructorship at the University of Maryland ended after the spring term of 1992 and in the fall of 1993 I began teaching engineering graphics (i.e. drawing and CAD) at North Carolina State University (NCSU). After reintegrating realms of knowledge in CAD for three years, at NCSU I was prepared to continue my work. This was not so easily done, as my teaching assignments were enmeshed within a culture and tradition of separating drafting from CAD, and technical knowledge from sociopolitical knowledge. Within a standardized curriculum where at least six sections of beginning-level engineering graphics courses are offered simultaneously, it was not so easy to deviate. Eventually I began experimenting in my sections of this 'foundations' course (GC 120), offered mainly for mechanical engineering students (GC was merely the course prefix standing for Graphic Communications). The first challenge was integrating drawing and CAD (Outline 4). The challenge was to teach the concepts of formal engineering graphics through the use of CAD (a version of CAD from the CADKEY company). Once this occurred, attending to sociotechnical content was easy, and the parallel of Outline 4 is the right side of Outline 3. I was actually reprimanded by my program coordinator for deviating from the established curriculum. Reluctantly, I was given a course section (GC/IE 210) of industrial engineering majors with which to carry on my experiments. I was unable to take the same sociotechnical approach that I took at Maryland: Much of the sociotechnical knowledge was introduced by me in lecture format. I made selections with regard to the volume of technical content that I was asked to 'cover', but my approach did not require a compromise. The sociotechnical knowledge enhanced the overall work of the students and by this time I had become fairly comfortable with the practice of reintegration. I eventually resolved the imbalances regarding the technical side of my career through STS, which supported the ethical-personal and sociopolitical sides of my life. I am not eccentric nor am I overridden with angst over technology. I am merely one forty-two year old white male who is trying to bring an end to technical education.

If in our CAD courses, we reintegrate procedural or technical knowledge with sociopolitical knowledge, our students realize that technical questions are actually political questions about how practices are organized. They realize that CAD in practice involves systemic organizational and social changes: changes to job content, organizational structures, procedures, rewards, training programs, and quite possibly entire organizational cultures. They see that innovation is an on-going, political process that involves a complexity of concerns. Through empirical studies that I synthesized and we discussed in CAD courses I taught, my students were moved from immediate, micro concerns to questions of technological determinism. They addressed Noble's (1984) thesis that CAD-CAM was historically configured to control workers, or eliminate them, and provide managers with an unprecedented mode of surveillance. They were forced to reconcile their own conceptions of automation and economic competitiveness with the empirical work that we discussed.

In teaching CAD, I took advantage of the experience-based nature of the courses: The students' work in CAD immediately and at once immersed them in sociopolitical content. CAD, like any form of education or tech-

OUTLINE 4
Teaching CAD: Technical approach (CAD w/drafting)

I. Graphic communications and CAD
   A. Design and Communication
      1. The design process
      2. Product life cycle
      3. Concurrent engineering
      4. Parametric design
   B. Social and Cultural dimensions
   C. The values
      1. Neatness and clarity
      2. Accuracy
      3. Standardisation
      4. Comprehensiveness
      5. Speed

III. Sketching and Visualization
   A. Tools
   B. Shape description in a 3D world
   C. Pictorials
      1. Oblique
      2. Isometric
      3. Perspective
   D. Multiview
   E. Plans and elevations
   F. Surface description
   G. Figured dimensions

IV. Engineering Geometry and Construction
   A. Simple 2D geometry
   B. Representation of 3D forms and shapes

V. Computer-Aided Design (CAD)
   A. Hardware and peripherals
   B. Software
   C. Systems software
   C. Data Handling
   D. Data storage
   E. Configuration

VI. CAD user skills
   A. Drawing editor, set up and tools
   B. Configuration
   C. Output
   D. Prototypes

VII. Entity creation
   A. Simple 2D geometry
   B. Text
   C. Blocks
   D. Simple 3D modeling
      1. World coordinate system
      2. Wireframes
      3. Extrusions
      4. Surfaces/Meshes
      5. Solids

VIII. Formal drawing theory and application
   A. Parallel projection
   B. Drawing styles and rationales
   C. Conventions and standards

IX. Multiview drawing
   A. Principal views
      1. Surface description
      2. Size
      3. Position/Location
   B. Sectional views
   C. Auxiliary views

X. Dimensioning
   A. Dimensioning theory & logic
   B. Symbology & standards
   C. Production dimensioning and tolerancing

XI. Manufacturing Processes
   A. Engineered fits
   B. GDT
   C. Threaded fasteners
   D. Welds
   E. Machine processes

XII. Detail and documentation drawing
   A. Shape description
   B. Figured dimensions
   C. Tolerances and specifications
   D. Title block

XIII. Working drawings
   A. Detail drawings
   B. Assembly drawings
   C. Bill of Materials

nology, is ‘always already’ political, and students came to question the values (e.g. precision, speed, standardisation) embedded in this technology. Organizational and sociopolitical content was not added on in the end of the course, nor was it assumed that this content would be dealt with in a separate course. Rather, this content was drawn from the students’ practices with CAD in the laboratory. My point here is that we have to make these connections explicit and attend to sociotechnical, not technical, knowledge. In so doing, we mark the beginning of the end of technical education. And we begin to bring an end to the production of two cultures. Nevertheless, some students would perennially write on course evaluations that 'I feel that Steve presented a broad range of CAD's potential', while other comments were similar to this: 'Social dimensions & etc. should be saved for a CAD II class'.

ETHNOGRAPHIES OF CAD IN SCHOOL PRACTICE

> [B]eyond iterations of cheerleading [for CAD and students] and warnings [about the limits of CAD], it was difficult for instructors to explain to students what was happening to them in the course (Downey 1998, p. 186).

As teachers, we are generally cognizant of the tension between supporting students to do what they want to do and supporting ourselves to get students to do what we think they ought to do. In my experiences with CAD courses, some students were naturally resistant to attending to some sociopolitical and technical issues. Their expectations of what a 'technical' course would do for them were different from my notions of what the course ought to provide. Somehow we sell students short by designing technical rather than sociotechnical courses, and we socialize students to expect the former rather than the latter. We continue to produce two cultures and proceed to privilege one at the expense of the other. So it is no surprise that in an ethnography of CAD in school practice, we read that 'students found the requirement to understand the positioning of CAD/CAM technologies in industry intensely boring' (Downey 1998, p. 154). But this observation says more about the politics of teaching than about the nature of knowledge. There are political differences in the ways that teachers choose to resituate a technology (CAD) in a particular context. Some ways – some histories, pedagogies and sociologies – can in fact be 'intensely boring'. As I described my experiences, the reintegration of sociopolitical with technical knowledge does not mean that we merely provide a timeline of technical events or an organizational chart of how CAD links with CAM in some utopian, industrial workplace.

The two CAD teachers in Gary Lee Downey's (1998) ethnographies designed their courses through a particular model of technical, in this case engineering, education. Their course outlines were conventional CAD course outlines (see Outline 1). In a conventional fashion, these teachers saw their responsibility as one of assuring that students understood that CAD was 'nothing but a tool out there to help' (p. 133). These teachers, Downey noted, 'often interpreted their pedagogical task as one of revealing the limitations of CAD/CAM technologies' (p. 158). This translated into a practice where the technical limits of CAD were grasped through lecture and trial and error. The students were taught that CAD was merely a technology used to manipulate information to serve the larger process of engineering design. The students were taught that CAD was adapted to this process and that they in turn would have to adapt to this new technology. The teachers' 'higher responsibility was to make sure that students would understand where they were and what they were doing when they encountered CAD/CAM technologies on the job' (p. 158). This translated into a practice where technical, not sociotechnical, competence was to provide students with an understanding of CAD in workplaces. Sociopolitical dimensions of CAD in practice were *not* made explicit in the courses. Two cultures were reproduced as the teachers explicitly placed artificial boundaries between user and machine, and politics and technology.

The students however experienced a range of relations with CAD. Some students struggled with the notion that a technologist would, to come to terms with this technology, have to submit control to CAD. Their experiences in the courses were marked by the intention to maintain control over the machines, and to express their relation as one of being 'in control'. Some students willingly submitted their agency to the technologies, feeling that adaptation was what was required. Others retreated to an objective to merely get through the courses and avoided questions of human-machine relations altogether. The students' confusion over relations, according to Downey, was compounded through the teachers' political positions that CAD was 'nothing but a tool'. If CAD was nothing but a tool, why were the students experiencing such confusion over their relations with technology? Why were some feeling disempowered over refashioning their selves to adapt to or control a range of values embedded in CAD? 'No one, not even the faculty', Downey suggested, 'had a vocabulary for routinely describing the location of CAD/CAM in industry as an activity that humans experienced as blurring the boundary between' themselves, society and technology (p. 154). While the most trenchant aspects of Downey's work come through his ethnographies of how students learn, and how teachers teach CAD, he demonstrated how rhetoric in the US's bid for competitive supremacy configured CAD and how CAD configured a generation of designers to distribute their cognition across machines (1992a, 1992b, 1993, 1998; Downey, Donovan & Elliott 1989).

Downey challenged technical teachers to move beyond the 'cheerleading and warnings' that characterised their pedagogies (p. 186). The CAD teachers he studied were conventional, he says, acting like 'disciplined messengers who transmitted [technical] knowledge without opening it for fear of perverting it' (p. 246). Similar to my conclusions here, Downey concluded that CAD and other courses could be avenues for reconsidering the false boundaries we have placed between humans, society and technology. Students, he concluded, ought to learn 'how to map the introduction and participation of CAD/CAM technologies in the workplace' as they attend to a wide range of sociopolitical questions such as those raised earlier (p. 246). Vanderburg & Kahn's (1994) case study of engineering at the University of Toronto, which ranks among the ten best North American universities, yielded similar findings and conclusions. Using a five-point assessment matrix to score technical courses on criteria beginning with 0 ('no reference to context issues') to 5 ('Substantial reference to context . . .'), they found that the overall picture was 'not reassuring' (pp. 357, 359). Context issues included implications of technology for ecology and society, ethical obligations of technologists, and implicit and explicit assumptions and values of technological practice. The mean score of the 50 courses assessed was 0.8, meaning that 'most of the courses are contextless' (p. 360). Like Downey, instead of suggesting course addenda or 'end of the pipeline' solutions, Vanderburg and Kahn argue for honest, systemic changes. To be sure, counter to what some aspiring design and technology educators (Bensen & Bensen 1993) have argued, engineering remains an inadequate candidate for bringing an end to technical education.

CONCLUSION: THE END OF TECHNICAL EDUCATION

Researchers in science and technology studies (STS) are in the process of dismantling the conventional human-machine and nature-society-technology boundaries solidified by C. P. Snow and generations of designers, engineers, researchers, scientists and teachers. At this point in time, there exists a wealth of research in STS that attends to any and all of the subjects with which we deal in 'technical' education (Pannabecker 1991; Petrina 1992). One can find detailed and fascinating studies of a wide range of technologies in the anthropology, history, psychology, philosophy, politics and sociology of technology. There is a rich fund of knowledge in ecological and feminist studies of technology along with studies that deal with multicultural issues. The research on CAD that I noted is not unique. There is literally *no* excuse to not attend to sociopolitical discourses in technical courses. I have argued elsewhere that technology studies are an interdiscipline in a multidisciplinary study of technology (Petrina 1998). But there is no way that we can replace technical with sociotechnical courses without becoming students of STS. As I'm discovering, there is *no* way our future designers, engineers and teachers will be able to do their job unless we who teach in post-secondary institutions do ours. To teach technical content in a technical course is now to assume only *half* of our responsibilities. Likewise, to abandon this responsibility to another course is to abandon any philosophy that underwrites our practice in design and technology education (Petrina 2002). If sociopolitical questions of CAD are not raised in CAD courses, where will they be raised?

My own sociopolitical knowledge of CAD is indebted to reading, reflective practice and workplace observations, yet there are numerous ways of attending to this knowledge in educational environments. Interviews with CAD workers are effective *if* students understand what sociotechnical questions to ask. In a CAD course, or another technical course, it would be easy to organize the laboratory or shop through a number of ergonomic, innovation and managerial models (Luetkemeyer 1989). The students could *feel* what occurs when CAD is organized through principles of Taylorism (scientific management). The one best way of doing mental and digital tasks is *not* a relic of the past; Taylorism is a real threat to work in CAD. How does it feel when someone or something is monitoring keystrokes, mouse clicks and ultimately mental productivity? How does it feel to work in a different environment, one that is marked by high trust relations? But in this same environment, tasks are loose and undefined. How does it feel when the CAD systems are arranged in such a way that they are uncomfortable, ergonomically and socially? How does it feel to be managed by someone who demonstrates a technological determinist's approach to innovation? How does it feel to have productivity linked tightly to technological innovation, which in turn is linked to interpersonal competition? Text readings are necessary, but readings are not the only way of attending to sociotechnical knowledge.

It will take small, yet significant steps to reintegrate, or rather dismantle, Snow's two cultures. After more than a century of attending to only technical knowledge in technical courses, it's time we seriously attend to ethical-personal and sociopolitical knowledge in these courses. If critical technological literacy (Petrina 2000a, 2000b) is going to have any chance of flourishing, we are going to have to crack the codes or break the locks of the most black-boxed of our curricula (i.e. 'technical' courses). Rather than leaping to nuclear power or genetic engineering, or to 'silicone breast implants, chlorofluorocarbons and DDT' (Wiens 1996, p. 25) to address 'impacts' of big 'T' Technology, we will have to step back and concentrate on the sociopolitical content of the small 't' technologies that we use everyday in the laboratories and workshops. It is time we moved far beyond the practice of asking students to generate a balance sheet to assess whether 'impacts' of Technology are 'negative' or 'positive' (e.g. Balistreri 1985).

Working from the labours of those who have moved the conversation from impacts, this article makes a clear case for the end of technical education (e.g. De Vries & Stroeken 1996; Gregson 1994, 1996; Hansen 1997; Lewis 1997; O'Riley 1996; Vanderburg 1992; Waks 1994; Wiens 1999). In 1985, Frank Pratzner made a brief argument to end technical education. He offered an alternative to the specialized skills and technological literacy of technical education (Petrina 2000a). Pratzner's notion of 'sociotechnical literacy' never took. To be certain, 'technical education' is suddenly in vogue again in North America. Witness the fairly non-contentious name change of the American Vocational Association to the Association for Career and *Technical* Educators in 2000. In BC, teachers and students talk about 'technical' education as a neutral practice between 'industrial' and 'design and technology' education. They sense the lack of currency in the title 'industrial' education and 'technology' education appears undefined, mis-directed and politically charged. Yet, as noted in the introduction, it is not worth splitting academic hairs between 'design', 'engineering', 'industrial', 'technical', 'technology' or 'vocational' education. Technical education is any of these practices where technical knowledge is isolated from sociopolitical knowledge. I argue, pure and simple, that we bring an end to technical education. Regardless of the name, we ought to be practicing nothing less than sociotechnical education. Perhaps our reference ought to be 'technology studies education' – the integration of technology studies (the TS in STS) with education and, in effect, the reintegration of sociopolitical with technical knowledge.

A hard lesson to be learned is that the way we organize knowledge, and our *relationship* to our technologies, are academic *and* political matters. It matters that we demonstrate the sociopolitical nature of technological practice. As Downey noted, it matters that we re-address conventional boundaries placed between humans and machines. If technology studies education is *not* about using classrooms, laboratories and workshops to promote technology, as technical education is in many ways, then what is the task of the teacher?

One reason design and technology teachers have little concept of what it means to reintegrate sociopolitical with technical knowledge is that they have been taught to disintegrate politics from technical cultures. Each fall I teach 30–40 technology pre-service, senior-year teachers about the untenable distinction of two cultures and ask them to reintegrate or dismantle the two. Each student is given an assignment to plan a ten-minute lesson dealing with any social issue surrounding a small 't' technology that they will be dealing with in the schools. In other words, I want them to deal with a social issue related to CAD, a hammer, or a transistor, rather than with genetic engineering. About 50% of the students typically draw blanks. As one commented in 1999: 'I have no idea what to do for this assignment'. Another said 'I just can't get my head around this'. They eventually deliver the lesson and most do an adequate job. The dissonance is healthy, but reintegrating sociopolitical with technical knowledge should not be that difficult for our teachers. Nor should this be something that designers and engineers must do in workplaces but not in schools. In the final analysis, Snow was right and Snow was wrong. There are two cultures, but they only exist in education.

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