# THE KNOWLEDGE WORKER AND THE FUTURE SKILL DEMANDS OF THE US WORKFORCE

**By**

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## Abstract

Can the sociology of work practice enrich our understanding of the future skill demands of the US labor force? The answer, I believe, is affirmative. I review the debates in the sociological and business literature surrounding the birth of a new category in the labor force: the knowledge worker. I demonstrate that both the sociological and business literatures have failed to define this term analytically. The sociological and the business debates have both been caught up in their own professional discourse (class structure and managerial challenges, respectively), and have paid little empirical attention to the realities of knowledge work. More attention should be given to the empirical examination of what knowledge workers do, what skills they possess and utilize in their daily work, and how their work is coordinated and controlled. Based on an emerging literature in the field of the sociology of work practice I describe the need for a more refined separation of types of knowledge (tacit, contextual, explicit) and reflect on the different ways knowledge is stored, manipulated and activated in work organizations. I also review the literature on new organizational and managerial practices aimed at coordinating and controlling the work of the knowledge worker. In the second part of the paper I develop my own occupational typology and claim that the most important change in occupational structure today is the expanding interface between knowledge and service work. This expansion is underpinned by a shift from the sale of a product to the sale of a process. This new interface requires revision of the ways we train our technicians and engineers. I use sales engineers as an ideal type occupation to demonstrate the types of skills these highly competent frontline workers employ. These include interactive social skills, networking skills, technological and social improvisation under high uncertainty, and the ability to deal efficiently with product ambiguity. Implications for training and educational programs are also discussed.

## Introduction

Creating, sustaining and documenting a knowledge economy has become a central goal of advanced industrial societies such as the USA and the UK (see Blair, 1998; Reich, 1993). Reich (1993), who sees the American knowledge sector as a key to sustained growth, claims that the number of symbolic analysts in the US workforce rose from around eight percent in the 1950s to around 20 percent by 1990. Analyzing occupational trend data between 1950 and 1990, Castells and Aoyama (1994: 23) confirm that white-collar work has expanded in the advanced economies, mostly among managers, professionals and technicians, whose occupations they term 'informational'. Barley and Orr (1997: 3) further claim that "The number of professional and technical jobs in the United States has grown by more than 300 percent since 1950" and that "no other occupational sector has experienced nearly as great a growth rate." This trend is expected to continue and even intensify. Hecker (2005: 71) analyzing BLS employment projection for 2004-2014, states: "Among the 10 major occupational groups, employment in the 2 largest in 2004 – professional and related occupations and service occupations – is projected to increase the fastest and add the most jobs from 2004 to 2014." A formal report by the European Union also predicted that "Up to 30% of the working population are estimated in the future to be working directly in the production and diffusion of knowledge … A large proportion of the rest of the workforce will need to be no less agile and knowledge based if it is to exploit new trends" (Europea Communities, 2004: 8 and 19). These data support the claim that knowledge workers have become a very large occupational group, and call for a better understanding of the nature of this kind of work and the types of skills it requires. Such understanding can assist in creating a better fit between educational programs and the future skill requirements of the American labor force. A more specific question which needs to be addressed here is this: Can the knowledge worker be defined in a way that conforms with BLS occupational classification?

The emerging information economy is quickly transforming the way we live. At work we depend constantly more on information technologies in diverse functions such as production, management and customer service. Our work is becoming increasingly mediated by computers (Zuboff, 1988) and we engage more often than ever in the manipulation of symbols and signs rather than the material realm. This socio-economic transformation of the workplace has given rise to a new occupational category: the knowledge worker, which has been the focus of abundant research in the past few decades. This category has captured the imagination of scholars and practitioners in different fields such as sociology, business, and education, but has not yet been formally recognized by the BLS. Partly as a result, the term knowledge work is poorly defined and therefore hard to subjugate to rigorous research. In the next section I grapple with the identity of knowledge workers.

## Who Are the Knowledge Workers?

Despite its wide use and the proliferation of studies on it, the term "knowledge work" remains poorly defined. Any attempt to understand its meaning and to identify the occupations it covers must first take a historical approach and examine how the term has been used within distinct debates. Sociologists in the sub-field of social stratification were the first to debate the rise of a new middle class composed of workers such as managers, salaried professionals, technicians, some salespeople and office workers (Mills, 1951). Forty years before Robert Reich’s (1993) influential book *The Work of Nations*, Mills, writing about the US labor force, argued that "as a proportion of the labor force, fewer individuals manipulate *things*, more handle *people* and *symbols*" (p. 65, emphasis in the original). Evidently, Mills was aware of the growing role of service and knowledge work in the post-war American labor force, a trend that has intensified in the past four decades. Although Mills does not explicitly use the term "knowledge workers" he asserts that most members of this emerging class come out of the working class as educated labor. His work prepared the conceptual ground for the heated debate on class structure that developed in the late 1960s and 1970s. The term 'knowledge workers' was introduced as part of this debate (Wuthnow and Shrum, 1983; Brint, 1984), by Daniel Bell in a 1979 article entitled 'The New Class: A Muddled Concept'. Bell argued that the economy by then was driven by information and knowledge provided by new professional and technical workers within the 'knowledge field' (p. 15). This 'knowledge class' consisted of occupations requiring workers with college and university degrees; a lengthy list of such occupations was provided, including scientists and scholars, mathematicians and economists, research physicians and law teachers. Here again, the emphasis was on formal academic training in the definition of knowledge work. While the sociologists were more concerned with the changing class structure, business scholars focused their attention on the managerial challenges and organizational implications of the rise of the knowledge sector.

In business scholarship, not unlike the sociological literature, the term knowledge work is defined broadly as white-collar workers, including teachers, lawyers, politicians, scientists, social workers, accountants and computer programmers. Also as in the sociological literature, the terminology describing these workers varies, and is often simply used with no reference to specific occupational groups or to a clear definition of the term. More recently, in his influential book cited above Reich (1993) labels knowledge workers ‘symbolic analysts,’ who "solve, identify and broker problems by manipulating symbols’ (p.178) and he claims that they are the key occupation for any nation wanting to pursue competitive advantage. Included in this category are research scientists, engineers, consultants, advertising and marketing executives, architects, film makers, writers, journalists and even university professors" (p. 178).

The sociological and business debates did not inform each another, but there are points of agreement between them. Both agree that with the ascent of knowledge work, the balance of power between employers and employees has shifted decisively in favor of labor. The reason is that the knowledge now critical for production resides intangibly within workers’ heads: it is the inherent property of the producer (the employee). As Despres and Hiltrop (1995: 11) state, "it remains with the employee and in no real sense is it ever of the firm … it is impossible to separate knowledge from the knower." Consequently, knowledge workers’ ‘product’, namely their ideas, "is extremely difficult to quantify" and the key technique and resource of their work – creative thinking – means that they also "control their own production" (Mandt, 1978: 140) or even "own the means of production" (Drucker 1998: 18; for a comprehensive review of the sociological and business debates about knowledge work see Darr and Warhurst, 2007). What is also common to sociologists and business scholars alike is a neglect of analysis of work practice in the knowledge sector.

The rest of this paper is dedicated to a review of a recent wave of studies in the sociology of work practice and to an analysis of the implications of their findings. I preface that with an outline of the strength and weaknesses of quantitative and qualitative methods of understanding skill and future skill demands.

## What Methods Are Employed to Study Shifting Skill Demands?

In his important theoretical paper titled "What Is Skill?" Attewell (1990), distinguishes four schools of thought on the concept of skill: Positivism, Ethnomethodology, Neo-Weberianism and Marxism. The first two are the most relevant to our discussion. By positivists Attewell refers to "…those who treat skill as an attribute that is amenable to quantitative measurement and believe that this attribute or quality has an objective character independent of the observer" (Attewell, 1990: 423). He points out that "creating a common yardstick," thereby facilitating comparison of skill level across occupations, is ":…the Achilles heel of [positivists – A.D.] studies of skill" (p. 423). The reason is that these measures must cover a wide array of skills in the complex world of work. In some cases, Attewell claims, positivists create a meaningful gap between the theoretical concept of skill and its operationalization. A good example offered by Attewell  is the term 'human capital,' widely used by economists since the mid-1970s (see Becker, 1975). This term is defined as the aggregation of knowledge obtained through schooling, training and on-the-job experience, which is quantified and then attached to a person. The problem here lies with the implicit assumption about the direct relationship between education, skill attainment and rewards in the labor marker. We all know that not all high-school or college graduates acquire similar levels of skill, yet their human capital will be similar. More important, sociological variables such as professional monopolies, gender biases embedded in occupational analysis and their impact on perceived skill level, and union effects are left out of this conceptualization (see Attewell, 1990: 426).

Government institutions have long tried to measure and quantify types of skills as well as the complexity of different lines of work. For example, much the sociological research on skill levels, which is based on the American *Dictionary of Occupational Titles* (*DOT*), combines three main dimensions out of the dozens of job attributes used by the DOT inspectors: complexity in dealing with things, with people, and with data, to create an overall measure of job complexity. Here, Attewell argues, sociologists lump together different types of skills to create abstract categories which are then hard to subject to rigorous measurements. As Barley and Orr (1997: 4-5) put it, "…government categories lump together occupations in an analytically naïve, if not haphazard, way." These authors further suggest that even the issue of "misclassification" of a specific occupation could be resolved, "…aggregate occupational data would still provide a hazy indicator of the shifting nature of work" since "…they index changes in what people do, but they are largely insensitive to changes in how people do what they do….". Spenner (1980, 1991) has also long argued that while the DOT in a key source for data on occupational skill levels, it should be used with caution. The DOT, Spenner points out, is not sensitive to certain sorts of skill variations; moreover, relying on this source for studies of content shifts of a specific occupation is not recommended given the risk of non-independence of successive DOT editions (Spenner, 1980).

Another danger in attempting to quantify skill lurks in the introduction of arbitrary or unreliable judgment (Attewell, 1990: 426). For example, the procedures of the inspectors who observe and rate different jobs can introduce what Attewell calls "culturally generated biases," specifically gender bias, and also assumptions regarding the supremacy of cognitive over manual skills. The categories used by the DOT inspectors may themselves be biased (ibid., 427).

The ethnomethodological approach is diametrically opposed to the positivist approach. It emerged in part in response to mounting critique of attempts to measure and compare skill levels across occupations and nations. Garfinkel (1969) is the founding father of this approach, with a powerful belief that almost any human activity is complex and cannot be conducted only consciously. He undermines the centrality of explicit knowledge and, more importantly, argues that skill has to be studied in a specific context and often cannot be communicated beyond locales. Skill acquisition, according to ethnomethodologists, is not linked to formal schooling but to on-the-job training and to the embodiment of cognitive and conscious abilities. Accordingly, you have mastered a skill when you no longer need to think about your activities, when they become automatic. Rule of thumb used by highly qualified workers is yet another example a body of knowledge and skills that have become embodied and no longer require explicit manifestation. Ethnomethodologists reject the supremacy of cognitive skills over manual skills, an assumption deeply ingrained in our cultural heritage and also manifested in some of the DOT classifications. Instead, they point to ways in which cognitive and manual skills are intertwined and cannot be analytically or empirically distinguished.

Is skill an attribute of a person or a job? Economists who use the term human capital claim that skill is the property of a person and it goes with her when she switches jobs. Sociologies that employ positivist approaches attribute skill level to a position or a job, rather than a person. Yet for the situated learning school, heavily influenced by ethnomethodology, skill acquisition occurs in the process of socialization into a community of practice, is context bound, and most importantly is the attribute of a community of practitioners rather than of individual workers or a specific job. The aim of social actors, according to this approach, is to move from a peripheral to a more central position, with a network of social ties that constitutes a community of practice (Lave and Wenger, 1991). For example, Rogoff and Lave (1984) portray skill as residing "…in the interactive work of the group as it unfolds in a particular setting" (Attewell, 1990:425). Here skill is embedded in the social relationship among workers. This approach is also echoed in some network studies of work practice which suggest that the knowledge required for efficient production is embedded in the structure of the social networks. Stated differently, social capital, namely the ability to access resources such as knowledge through a network of social ties, becomes a major asset of individual workers and communities of practice as a whole.

Based on the critique of the positivist approaches to the study of skills, should we abandon attempts to quantify and compare skill levels across occupation and over time? The responsible answer, I believe, is no. First, we don't have a real alternative when aiming to analyze and forecast the changing skill demands. More importantly, we know that there are ongoing attempts to improve the quality of data in the DOT. While we will probably continue to employ quantitative means of measuring skills, we should nevertheless take into account some of the insights of ethnomethodologists. For example, before we endeavor to study knowledge work and knowledge workers using large-scale surveys, we might want first to pay close attention to the findings of ethnographic studies and case studies in this sector. These studies, which bring native perception and daily work realities to the surface, can then be used to construct occupational titles, terms and questions which could be used for large-scale quantitative studies.

Ethnographic and case studies of work practice have advantages and shortcomings which need to be addressed in brief. In case studies and ethnographic studies no representativity of the results is claimed, and this is a major disadvantage. A limited solution is a comparative design in which two or more case studies are contrasted and compared. The strength of any case study lies in guiding future researchers exploring similar topics. As Bechky (2006: 1759) writes, relating to Orr's thick description of Xerox technicians' work: "Orr's study provides the empirical data on work practice to stimulate theorizing about the future of work and organization." By exposing employees' systems of meaning, case and ethnographic studies can prevent the imposition of theoretical concepts onto the empirical realm. Case study methodology also allows examination of processual issues in great detail. Finally, some of the studies cited below focus on small engineering firms, and the firms' size might be thought to bias the results. But in the organization of engineering labor, these small firms show similarities to industry-level trends. As macro data indicate (U.S. Department of Labor, 1985, 1988, 1991), R&D and sales engineers are two sub-groups of growing importance in the micro-electronics industry as a whole. This fact, coupled with the growing prominence of ‘engineering boutiques’ in micro-electronics (McLoughlin & Clark, 1994), makes these small high-tech firms fairly typical within their industry. In the next section I briefly discuss the different types of knowledge employed by knowledge workers.

## What Types of Knowledge Are Important in Knowledge Work?

The sociology of work practice makes a clear distinction between types of knowledge (tacit, contextual, explicit, etc.: see Barley, 1996; Pinch, Collins and Carbone, 1997). By making the distinction scholars try to shift the debate about the nature of knowledge work from the more abstract context of class formation or managerial challenges to the daily work practices of highly skilled workers. The main distinctions between types of knowledge are the following.

*Explicit or formal knowledge*: This type of knowledge is easily articulated and transferred through the use of written documents, schematics and formal models and forms. It can be easily symbolized, automated, and, most important, communicated and interpreted beyond a specific social context.

C*ontextual and tacit knowledge*: In contrast to formal knowledge, contextual and tacit knowledge are non-codified and embedded locally; they are non-standard, and thus cannot be easily articulated or understood outside a specific social context. *Contextual knowledge* cannot be easily deconstructed to a machine-like code, nor can it be readily transferred to another site. It becomes relevant not in the abstract but in light of specific work-related problems. Summarizing a group study of technical work and referring specifically to technicians, Barley (1996: 425) notes that since "…problems involved unanticipated troubles, technicians found they had to piece together most of the information necessary for solution from the situation itself." He further indicates that "Under such conditions, the utility of formal training appeared remote." The term *tacit knowledge*, as I understand it, is a bit different than contextual knowledge, although both are frequently used interchangeably in the literature. Tacit knowledge cannot even be transferred to another person and is learned through personal experience and engagement in work practice. Hence, both contextual and tacit knowledge cannot simply be automated or learned through formal means. They need to be transferred via personal experience, social ties and shared practice (Collins, 1995). Knowledge workers engage in and acquire all types of knowledge in their daily work, and any understanding of the nature of work must take articulated, contextual and tacit elements of knowledge into account. Finally, the sociology of work practice has identified additional types of knowledge, such as embodied (Collins, 1995) and semiotic (Barley, 1996) among others.

## Which Types of Knowledge Characterizes Different Lines of Work?

According to the sociology of work practice, instead of talking about knowledge work in the abstract we first need to define which combination of knowledge types is employed by different knowledge workers. This tradition in the sociology of work originated in ethnographic and ethnomethodological studies of science labs (Latour and Woolgar, 1979), and is well exemplified in the sociology of work practice in the study of Barley and Bechky (1994) on technicians in science labs. Unlike the public image of science, and even the self perception of many scientists, these studies demonstrate that scientific practice is not guided only by explicit formal knowledge but also by tacit and contextual elements of knowledge. In recent years we have seen a surge of studies pointing to the centrality of tacit and contextual knowledge in the work of other knowledge areas such as computer technology, engineering and even veterinary medicine (see Orr, 1996; Barley, 1996; Pinch et al., 1997; Darr and Scarselletta, 2002). This line of studies challenges the emphasis on formal scientific education as a key to future skills demands. Instead it might suggest a need to shift educational programs toward exposure to the way knowledge work is actually carried out, as against the science-like image of this line of work.

## How Is Knowledge Stored?

To those who equate knowledge only with its explicit manifestations the question presented here might seem superfluous. After all, formal and explicit knowledge is stored in computers, computer networks, standard forms, and a formal division of labor. In fact, most of the early literature about organizational memory, and more recently the plethora of studies on knowledge management, have been guided by this rather naive perception of the way knowledge is stored in work organizations. Still, recent studies in the sociology of work practice again challenge these assumptions, suggesting that knowledge critical to accomplishment of work tasks is kept in oral form and is the property of occupational communities rather than organizations (Orr, 1996; see also special issue of *Organization Studies* (2006, vol. 27(12) which includes review articles and comments on this important book). Knowledge held in oral form is more flexible and responsive to changing work realities than the formal manuals that management requires Xerox technicians to carry with them for perusal when they debug faulty copy-machines. The suppleness of critical knowledge stored orally makes for creative problem solving, but Orr also analyzes it in the framework of the constant tension between management and workers: oral storage keeps critical knowledge outside the reach of management and enhances the technicians' occupational power and autonomy. This tension and its role in shaping knowledge work are often missed in business studies of knowledge work. I elaborate on this topic in the section on emerging coordination and control mechanisms.

Innovation and innovative thinking can also be shaped by the structure and content of the occupational network as a whole, and of the individual actors within it. Casper and Murray (2005), comparing bio-technology clusters in Cambridge, UK and Munich, Germany, demonstrate how the two clusters differ in their social capital. Unlike the Cambridge case, in "Munich biotech firms have limited access to the commercial development expertise in big pharma" and, in addition, the lack of referral networks with big pharma companies "who may be important alliances partners…" (p. 72) may impact the firms' reputation. Another example is Kreiner and

Schultz's (1993) study of the Danish bio-tech field, in which personal ties constructed through shared schooling furnish the social infrastructure and trust necessary for the development of collaboration between universities and industries. Expert knowledge residing in network ties connecting itinerant experts is also emphasized by Barley and Kunda (2004). While this section has attempted briefly to discuss the place of knowledge, we now grapple with this question: What does a worker needs to do with knowledge in order to be considered a knowledge worker?

## What Is Done with Knowledge?

Questions arise as to how much knowledge a worker must possess to qualify for the title of knowledge worker and what needs to be done with this knowledge . For example, can a clerk working in an archive be considered a knowledge worker? Is (teachers') transferring knowledge in a creative way sufficient for this purpose? To be considered a knowledge worker, does a worker need to manipulate knowledge, and if so to what degree? Should the degree of interpretation required by a worker of the information being processed determine her occupational title? Sociology of work practice raises these questions (but not the answers) to point out the loose way in which the term knowledge work is defined and used by sociologists, economists and business scholars. Any attempt to define knowledge workers in a way that conforms with BLS occupational classifications must take these questions into account.

## Coordination and Control in the Knowledge Sector

Knowledge work is hard to coordinate and control, partly because in Information Technology markets the Weberian assumption regarding an overlap between organizational position and skill level no longer applies. In the ideal-type model of a rational-legal bureaucracy, workers who perform better than their peers are promoted to managerial positions, and as they move into the higher echelons they acquire new managerial skills and formal authority while maintaining their old skills acquired on the production floor. Given a stable environment, they can easily direct and coordinate the work process. By contrast, when knowledge and skills central to production process are constantly in flux, the young workers often know much more than their superiors, who are unfamiliar with the types of knowledge and skills they employ in their daily work. This situation obtains in the software industry, where core programs change every few years. The knowledge gap between managers and workers, coupled with the growing dependency of organizations on skills and knowledge held by occupational communities, poses a challenge to the management of knowledge workers. To complicate things further, there is a growing need to retain knowledge workers in the highly competitive IT market. In the following pages I outline some of the findings of the sociology of work practice regarding managerial measures designed to coordinate and control the knowledge workers. Since engineers move into managerial positions as an integral part of their career, integrating some of these findings of sociologists of work practice into the engineering curriculum might prove beneficial.

**Market control**: Direct, technological, and bureaucratic means of control have been systematically investigated by the research literature, and have been associated with the industrial revolution, the rise of Fordism as a leading production paradigm, and post-WW2 industrial growth, respectively. Partly in response to prominence of knowledge workers since the 1980s, market control should be added to the list (Darr, 2003). For knowledge workers such as sales engineers, market control meant two things. First, their technical expertise now involved much more than simply responding to and interacting with clients. Their responsibility embraced keeping a close watch on the prices of electronic components and minimizing production costs as part of customizing their products. If a customized project brought in no profit management saw this as failure by the sales engineers. Repeated failures resulted in layoffs. Second, the client's engineers and managers became the supervisors of the sales engineers' work, as they composed a quasi-firm arrangement during the lengthy customization process. The cross-firm expert ties that developed between the sales and the clients' representatives were based on professional engineering norms. The managers of the selling organization asked the clients' engineers and managers about their satisfaction with the work of their own sales engineers. Similar practices are used in call centers to assess the quality of technical support. For the selling organization this is a way of outsourcing part of its control apparatus, thus cutting the cost of supervising the quality of the knowledge workers holding frontline positions.

**Strong engineering cultures:** Since employers wish to harness the knowledge worker's creativity and enthusiasm, and more traditional means of control are insufficient in this respect, some of them invest in acculturating their workforce. For example, Kunda (1992) in his important ethnographic depiction *Engineering Culture,* and Kidder (1981) in *The Soul of a New Machine*, describe how values and organizational norms are instilled in workers through an array of ceremonies, symbolic remuneration and peers' normative pressure to ensure their ongoing devotion and loyalty. The slight paradox here is that since the means of production in knowledge work are stored in knowledge workers' minds, managers need to devise new ways to control the work process. Their solution is some cases is to make knowledge workers' hearts the target for managerial manipulation.

**Responsible Autonomy and deadlines:** In her study of a small Australian software company, Barrett (2001, 2004) suggests that in IT organizations continuity in implementing control mechanisms is as important as change. She points to a range of strategies used by employers to gain control of the knowledge workers which include old and new ways. Citing Sharpe (1998: 364) Barrett calls this old-new combination "control and inspire." Alongside wide autonomy in managing their daily work, a highly flexible schedule and encouragement to experiment with new ideas and technologies, Barrett found the more familiar weekly meeting, frequent goal settings, employee performance appraisal and strict deadlines. Failure to deliver a software product by the deadline is often followed by layoffs. This is another indication of output control, which dominates the IT market given the difficulty of controlling inputs and process.

**Employing occupational control in horizontal divisions of labor:** Barley's (1996) technization thesis postulates that horizontal or occupational divisions of labor are becoming more central to production processes, specifically in high-tech markets. Increasingly, organizations are unable to contain all the knowledge and skills they require for their production activities and must allow their workers to engage in collaborative work with members of their occupational communities outside the firm. Since the locus of innovation in bio-technology as well as software is constantly shifting, collaboration with experts outside the organizations imparts greater certainty to firms (Oliver and Liebeskind, 1998). What governs these collaborative networks are not formal contracts but trust, mutual dependency and professional norms (see

Kreiner and Schultz, 1993). For employees involved in informal collaborative work, maintaining their image as experts within their community of practice becomes a major incentive to perform well. One might argue that managers and engineers in supervisory positions in the knowledge sector should find ways to enhance their employees' connections with their occupational community and use occupational rather than bureaucratic forms of controls.

## Part II: The Rise of a Techno-Service Sector

### The Growing Interdependence of Service and Knowledge Work

Two seemingly opposing trends shape the current landscape of the American workforce. On the one hand, ample data point to the rapid growth of the service sector, typically described as producing low-skilled and low-paid jobs. On the other hand, the literature is replete with studies heralding the birth and rapid growth of the knowledge sector, composed of highly skilled individuals who hold college degrees and enjoy wide occupational autonomy and a high salary. These opposing trends seem to contribute to the polarization of the US labor force, that is, to the dwindling of semi-skilled jobs and of the middle class as a whole (for a review and critique of this thesis see Autor, Katz and Kearney, 2006). Figure 1 graphically depicts these two trends.

Figure 1: Major trends in the US Labor Force


While both trends seem to be well grounded in empirical research, sociologists as well as economists tend to treat them as vectors pointing in opposing directions. But they fail to identify the growing interdependency of service and knowledge work since they use ready-made occupational classifications and do not attempt to critically examine the changing nature of work within occupations. I claim that the robust interface between service and techno-scientific work (which here I equate with knowledge work) creates new skill compositions and blurs traditional divisions of labor. The growing interdependency of social and technical skill is rooted in a shift in advanced economies from sales of a product to sales of a process in high-tech markets, and carries important implications for educational programs.

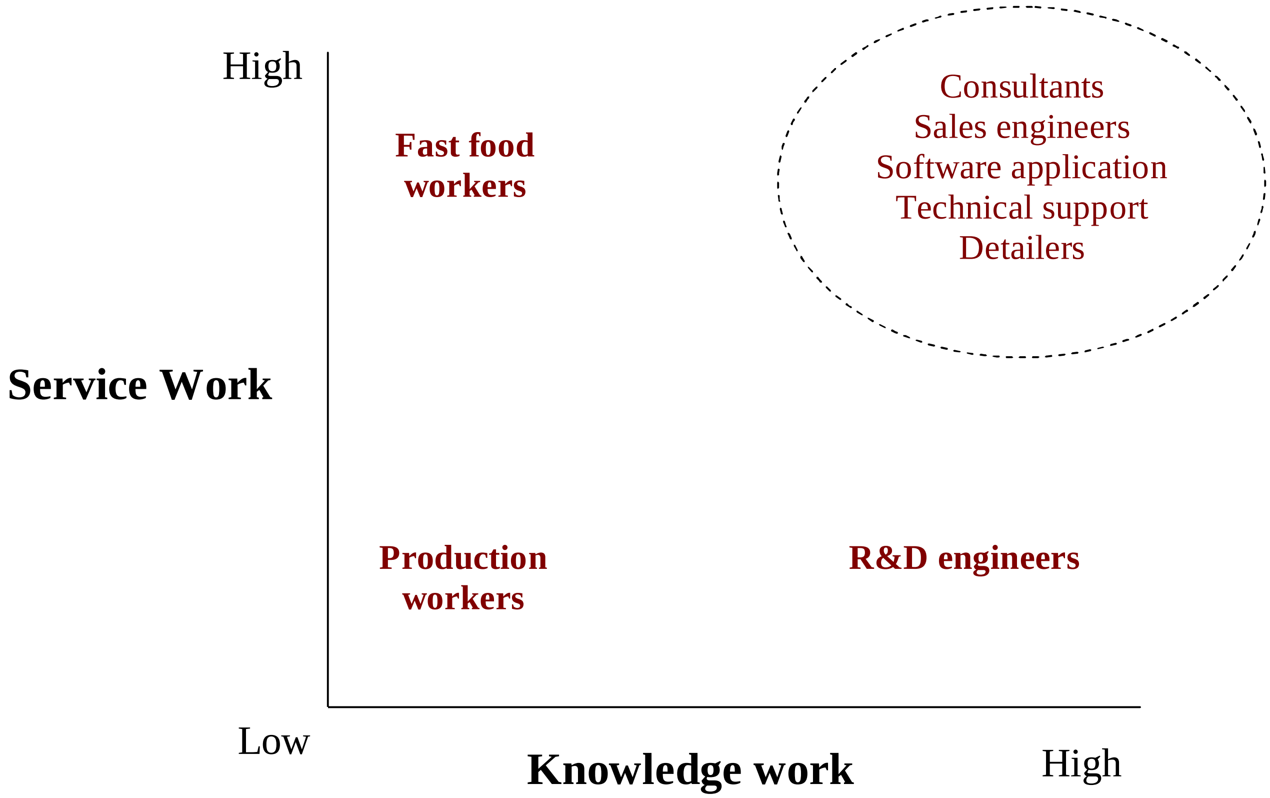
In emergent technology markets the substitution of a process for a product is grounded in the lack of a clear agreement between sellers and buyers about the future use of products. For example, in the software industry sellers often sell a concept, a goal which must be negotiated and customized through a lengthy process. Likewise, software implementation (e.g., ERP systems) and various consulting jobs involve exchange of a process rather than a traditional product. More generally and in other industries, a few scholars (see Pine, 1993) have claimed that "mass customization" is substituting mass production as the main production paradigm. Computers and computer-integrated machinery, according to these writers, allow service and manufacturing firms to shift from mass production to mass batch production or mass customization. This flexibility in production also accelerates the shift from selling a product to selling a customization process. Selling a process causes technical experts to stream to frontline positions where they interact directly with the clients' representatives.

Knowledge has always been utilized in work practice. My position is that what is new about knowledge workers is the increasing integration of service and technical skills. The polarization thesis is based on income distribution of aggregate occupational data, which do not provide indicators of the different ways in which work is carried out within existing occupational titles. While I do not dispute polarization, I am opposed to the assumption that polarization occurs along the traditional service-knowledge dichotomy. Instead, I maintain that a closer look at the changing nature of work will highlight the need to rearrange our aggregate occupational data so as to include special categories for a hybrid form: the techno-service sector.

The growth of techno-service jobs has already made an impact on the US labor force. For example, Hecker (2005: 71) in his analysis of the BLS occupational employment projections for 2004-2014 states: "…professional occupations are projected to grow the fastest, chiefly because they are concentrated in some fast-growing sectors, such as health care and social assistance as well as *professional, scientific, and technical services* …" (italics added). In addition, out of the ten fastest growing occupations presented by Hecker (2005: 75) three, I claim, combine sophisticated knowledge and skill with service elements (Network systems and data communications analysts; computer software engineers, application; and computer software engineer, system software). Others such as dental hygienists and medical assistants can also be seen as members of the techno-service sector. The growth of a techno-service sector poses a substantial challenge to our educational institutions, which tend to view knowledge workers as the ideal type of industrial R&D engineers or scientists. I suggest that simply offering students more of the same (e.g., enhancing science and math classes in K12 and undergraduate programs) will not create a better fit between many of the graduates and future labor market demands. Instead, new types of skills such as interactive social skills should be integrated into engineering and scientific training.

Figure 2 below represents my attempt to move away from portraying service and knowledge work as opposite trends and instead to create a typology based on the degree to which knowledge and service elements are intertwined in a specific line of work (see Darr, 2007).

**Figure 2: Occupational Typology Based on Service and Knowledge Elements**




As figure 2 shows, traditional manufacturing jobs are low on both service and knowledge elements. Burger flippers and waiters are high on service but low on knowledge elements. Scientists and R&D engineers, who are typically buffered from market exigencies, are low on service elements but high on knowledge elements. However, I believe that at the core of the so-called "knowledge economy" is the rise of a group of occupations that combine service and techno-scientific elements in their daily work. These occupations include, but are not limited to, software application engineers; technical support; engineering and scientific consultants; software implementers; some qualified call center workers and detailers. An ideal type of these occupations is sales engineering.

A small but growing body of literature in sociology of work practice has recently suggested that sales departments in industries leading the current transformation of the socio-economic infrastructure are undergoing a technization process (Darr 2002). For example, in US leading-edge industries the percentage of engineers holding formal academic degrees in the sales force almost doubled during the 1980s, from 12 percent to 22 percent (US Department of Labor 1985, 1988, 1991). The BLS figures project a growth of 14 percent in the number of sales engineers in the years 2004-2014. Similarly, sales support in the software industry increasingly involves technical experts (Pentland 1997).This is a clear, yet limited, indication that knowledge and service work are intertwined. Increasingly, firms are oriented to their clients and must enhance their workers' social skills to provide quality service, in addition to exhibiting technical competence in producing high-quality goods. The sales engineer is but a key example of an emerging cluster of occupations where social and technical skills are interdependent.

## What Do Sales Engineers Do?

This section is based on an ethnographic study of the sale of emergent and standard technology in the USA. The full results appear in Darr's ***Selling Technology: The*** *Changing Shape of Sales in an Information Economy*, published in 2006 by Cornell University Press. In the market for emergent technology that I studied [real-time computing], the sales force was mostly composed of engineers, with formal academic training, who were called sales, customer, or field application engineers. The sales engineers rarely visited more than one client a month. On their sales visits, which lasted a week on average, they met the client's test and design engineers, negotiated the technical features of the client's application, diagnosed and solved technical problems with the products their company had delivered, and offered training sessions and even post-sale support in some cases. Technical salespeople also spent up to a week per month participating in specialized trade shows, where they collected information about prospective clients and new applications for their products. They endeavored to identify applications and clients that required as little adaptation of their products as possible. Accordingly, one of their main tasks was to ensure that the customization process would be cost-effective.

During the industrial era the vast majority of products were characterized by common expectations about use. But in emergent technology markets, where many knowledge workers are employed, not all products have this fixed and common set of uses. In fact, at the cutting edge of technology sellers and buyers often hold radically different interpretations of product application. Von Hippel, (1988) finds that “lead users” (large buyers) are major innovators in micro-electronics since they often put innovative tools and techniques to use that diverge from manufacturers’ expectations. If we assume that products in high-tech markets often enjoy an interpretative flexibility (Pinch and Bijker, 1987) and that some sellers and buyers do not have a common image of use, we can understand why we find engineers working in frontline positions. They need to negotiate the technical details of the customization process as well as learn about new user applications for their products which might be developed into niche markets. Most sales people in the real-time computing market that I studied had a strong engineering background, often design engineering. They employed this knowledge in the process of customization work, as well as a range of other skills rarely associated with engineering.

## What Types of Skills Do Sales Engineers Employ?

*Interactive social skills*: Unlike the case of mass-produced or craft-produced goods, a major source of uncertainty in the sale of emergent technologies is product application. From the initial stages of the sales process the sales engineers tried to understand how the client would like to use their product and to assess the feasibility of the customization process. To succeed in this, the sales engineers had to employ interactive social skills, namely skills associated with the efficient management of social interaction to the benefit of the employing organization (for the case of interactive service work see Leidner, 1993: 2-3). More specifically, I refer to the process whereby the sales engineers and the client's engineers communicate and assess technical knowledge, which is rooted in work practice. Here seller-user interactive learning is vital for the successful development of innovative products, as this knowledge is “encultured” in occupational communities of experts (Collins, 1995). The screening process employed by the sales engineers during opening sales interactions at trade shows provides a good illustration.

Specialized trade shows in real-time computing help crystallize an amorphous market into concrete form. The sales engineers did not expect to sell during the trade shows, but they did expect the shows to help them better understand who their clients were and how they would like to use their products. Typically, when visitors approached a salesperson's booth they picked up one of the boards on display and asked, "What is this, what does your product do?" After a brief description, the salespeople directed a series of questions at the visitor, designed to assess him or her as a prospective client. For example, after a brief explanation of what the computer boards he was selling were designed to do, a sales engineer at a show in real-time computing asked a group of engineers visiting the show: "What types of things are you guys doing?"  Salespeople would then try to find out the exact projects the visitor was working on. In a local trade show in Dallas, Texas, I stood near the booth of a company offering VME single board computers and PCI add-in boards. One of the visitors approached and picked up a circuit board. He touched a chip bearing the name INTEL 360, and inquired what the board was designed to do. The salesperson replied it was a powerful computer designed to transfer and process digital data in real-time. He also described the industry standard the board adhered to:

*Seller*: This is a VME bus, and we also have [boards for a] PCI industry standard. What do you need it [the board the customer was holding] for?

*Buyer*: It is a new project. [*Looks around and then whispers something I could not pick up.*]

*Seller*: Do you use a VME bus?

*Buyer*: Yes.

*Seller*: What sorts of interface?

*Buyer*: Oh, well, we have VME, SCSI [Small Computer System Interface].

*Seller*: Do you use something like C3 ETM?

*Buyer*: I don't know, we have not decided yet.

*Seller*: Until you determine what kind of interface you would like to use, there is little we can do. [*The seller smiles and offers his hand for a handshake]*

*Buyer*: Yes, that's right, thank you. [*Shakes hands with the seller*]

*Seller*: Thank you.

This interaction exemplifies how interactive social skills are employed as part of a sales interaction involving technical experts. Note that the sales engineer, not the buyer, initiated an information search to learn about the client’s application. The sales engineer first asked which industry standard the client planned to use, to learn if the board he offered for sale could suit the client's application. Next the seller asked for the specific application. Then, learning that the system's interface had not been decided yet, the seller was not sure his product could actually work as part of the system. More important, the potential client’s response ("We haven't decided yet") was an indication that the design process was in its early stages. At this point the sales engineer realized that the application was not feasible and decided to end the interaction by sticking out his hand for a quick handshake. (For a more detailed description see Darr, 2004).

In the later stages of the customization process, and after the contract was signed, the sales engineers and the client’s design and test engineers formed a distinct work unit, and jointly engaged in co-development. This involved frequent face-to-face interactions, the sharing and replication of experiential knowledge, and the development of shared interpretations of product application. To ensure the success of co-development the seller's and the buyer's engineers had to develop a technological dialogue (Pacey, 1990) through social interactions and shared practice. The sales engineers had to integrate the input of the client's engineers and allow their own perception of the customization process to evolve over time in accordance with the client's needs and demands. Here too, interactive social skills proved pivotal to the success of the customization process.

In other cases the client’s engineers felt the new device sold by the sales engineers might undermine their authority, and they tried to prevent the transaction.

The sales engineers went on to describe negotiation tactics that could defuse the threat imposed by the device they sold and customized.

*Building and employing social capital within a community of practice*: Today agreement is growing across disciplines (e.g., sociology and economics) that workers' social capital is as important as technical skills as an asset to a firm's performance (Green 2000). Social capital includes the resources that actors can access and mobilize through their embedded ties with other actors within a social network. Social capital is also "created when the relations among persons change in ways that facilitate social action" (Coleman, 1990:304, cited in Knoke 1999:19). Actors' social capital is developed mainly through social interactions, and new social ties provide social actors with new learning opportinities. The centrality of social networking is apparent in the work of the sales engineers.

Once a contract is signed the sales engineers focus on the construction of working ties with the client's engineers, and management of the flow of explicit and contextual knowledge as to the client's application. The sales engineers have to solicit the cooperation of various members of the client's technical staff. Rather than relying only on universal norms such as reciprocity, the sales engineers need to activate professional networks to identify the best informants in the client's plant. As in the case of lawyers (Tolbert and Stern, 1991: 101) outside salespeople refer to their relationships with buyers as a tangible asset.

Choosing the right contact or informant at the clients' plants was not easy because the problem, as sales engineers often put it, was to find the client's engineer who was actively involved in designing or testing the application. When asked who on the client's side they were searching for, one sales engineer selling a computerized testing device replied, "I'm looking for the engineer who actually designed the board to be tested." To identify the right informant, or "contact," salespeople in real-time computing consulted their peers and engaged in long telephone conversations with several of the client's engineers. Here again, they activated their social capital, a pre-existing network of social ties within their occupational community (Van Maanen and Barley 1984).

Another example is from a case study I did of a small startup firm operating within a technological incubator in upstate New York affiliated a leading research university (see Darr, 2000). The company developed test instrumentation and software, and later introduced a computerized tester for printed circuit boards, which enabled manufacturers to identify faulty boards on the production line, instead of shipping finished boards to a quality control department. During a coffee break a customer engineer told me and a group of  R&D and customer engineers how he was able to locate an engineer who designed a board for which he had to develop a test, even though this engineer had switched companies twice since he designed the board. The customer engineer claimed he had saved himself the need to reverse-engineer the board. From their reaction, the other customer engineers evidently perceived the speaker's actions as highly skilled. In sum, sales and customer engineers positioned the mechanics of constructing and maintaining informal ties with clients at the heart of real engineering. Social gatherings provided the setting for constructing and enacting an image of the sales engineer as a socio-technical expert who manages relations with clients as part of the customization process.

*Interviewing skills:* Product demonstrations were an important feature of the trade shows in real-time computing. Buyers' test and design engineers who participated in the demonstration typically had a specific technical problem in mind. A typical question from a client at the start of the demonstration was, "Could this board add memory power and interact with a VME BUS?" or "Could this testing system be integrated into a production line and be operated by production workers?" The clients' questions assisted salespeople in presenting features that could address the specific problem. As the salesperson took the clients through the specific feature, the client often reacted by offering a detailed description of related problems and allowed the salespeople to suggest other features of their product as a possible remedy. By encouraging the client's engineers to experiment with the product and to share their thoughts with them, the technical salespeople extracted additional contextual knowledge about the desired use of their product. They were also able to present their product as a solution to the client's practical problems, and thus started to integrate their product into a body of contextual knowledge possessed by client's engineers.

*Efficient problem solving under product ambiguity*: Standardization, certainty and planning are pillars of the industrial age. By contrast, the post-industrial era is characterized by greater uncertainty and product ambiguity, partly as part of the fast pace of technological change. For example, the sales engineers I studied suffered from "client uncertainty" as I call it, which obviously does not exist in the mass market, in which any controversy about product design and use has been long settled, and in which products are standardized and mass produced.  To overcome the uncertainty about the identity of prospective clients expressed in the above quote, salespeople engaged in a specialized search for sales partners, in sharp contrast to sellers' general and unspecialized search behaviors in a mass market. For example, the "guesses" about prospective clients made by this salesperson and his company were actually educated ones. The trade show in which his company introduced its new product was a highly specialized show in real-time computing. In addition, the salesperson approached a small number of firms participating in the show only after he had collected information about their products at a previous show. This example is also telling because it implies the seller's need to understand the client's application. Such a need did not exist in the mass market studied.

The lack of a shared image of use and the need to customize products required salespeople to assess carefully the feasibility of possible applications for the products they offered for sale. Salespeople in real-time computing were always looking for new uses for their innovative products; new applications meant new potential clients. But not all applications were economically feasible for the small engineering firms that constituted the majority of manufacturing firms in real-time computing. Some level of customization, which was labor-intensive, risky, and costly, was required as part of a sale. Thus, the feasibility of customization was another important source of uncertainty for sellers (Darr, 2006).

*Emotional labor*: My study of the sales engineers was comparative, and it is important to note that they engaged in emotional labor to a lesser extent than the salespeople of passive electronic components. On one occasion I observed a technical salesperson standing at his display booth. Suddenly he identified a visitor who had been close to buying from him a year before, rushed over to him, grabbed him by the hand, and walked him to his booth. He reminded the visitor that he had visited his university lab twice, and that he ended up buying from a competitor. The customer, clearly embarrassed by this blunt attempt to make him feel guilty about that, was silent. Then he said: "We're thinking about buying a new testing software." The salesperson looked pleased and told his colleague, who was in charge of running the product demonstration: "Well, Joe, just go ahead and give him the full demo." Here, we see an example that technical sales also involved emotion management.

*Cultural skills and diversity management*: Knowledge workers operate within a global economy, and globalization bears on their daily work. The sales engineers spent much of their time traveling to clients' plants and R&D facilities, which were often located outside the USA. Their encounters with Mexican and Singaporean engineers sometimes left them frustrated. Although I have scant data on these cross-cultural encounters, it is clear that engineers must be educated to face and even benefit from globalization. The need for engineering education to adjust itself to some of the consequences of globalization is already reflected in some of the literature. As Tryggvason and Apelian (2006: 17) point out, "Not only are engineers frequently working on products that will be made in a different country and marketed to people of different cultures, but product engineering is increasingly done by teams consisting of people located in different countries and with diverse cultural background."

## Implications for Educational Programs

The engineering profession in the USA emerged out of a craft tradition only about 150 years ago, through the modification of scientific methods for application to the systematic study of artifacts rather than nature (Layton, 1976: 695). Major forces behind the professionalization of engineering were the Federal Government, a public outcry following major technological failures, and the work of leading engineers such as Isherwood, Thurston and Taylor, who brought about the rise of "engineering science" (ibid.). Today craft and scientific traditions are intertwined in engineering, and the tension between abstract scientific knowledge and hands-on experience has figured prominently in the development of engineering education (for a recent example see National Academy of Engineering, 2005: pp. 54-55).

The systematic examination and periodic modification of engineering education has come largely from inside the profession. Seely (2005: 114) writes: "Engineering education has been the subject of more studies and reviews, formal and informal, than any other domain of professional education." Today pressure seems to be mounting from industry and from within the profession to re-figure engineering curricula and to adjust young engineers better to the changing realities and skill needs of the future labor market. The review of the sociology of work practice that I have offered might help in stimulating a few new ideas toward such a revision.

Many of the categories scholars use in studying work organization and management were elaborated in the manufacturing era. Some of them no longer apply to contemporary work organizations. For example, the work of technicians in high-tech settings is neither blue-collar nor white-collar. Instead, technical experts combine intellective and manual skills in their work (Barley 1996). Similarly, the interdependence of social and technical skills seems to be increasing in some areas of the knowledge sector, namely technical sales and sales support. More and more workers, like the sales engineers described here, must combine and master the two types of skills in their daily work. In consequence, sticking to the distinction between social and technical skills in engineering education will fail to address the shifting skill needs in contemporary work organizations.

One of the most recent efforts to discuss engineering education for the year 2020 contains the following statement: "Technical excellence is the essential attribute of engineering graduates, but those graduates should also possess team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies" (National Academy of Engineering, 2005: 52). Another publication (National Academy of Engineering, 2004: 55) declares: "We envision a world where communication is enabled by an ability to listen effectively as well as to communicate through oral, visual, and written mechanisms." Thus, some of the themes I will discuss have been mentioned already, but not necessarily developed in the direction I outline below. For example, as we see above, the need to improve engineers' communication skills has already been acknowledged, and many engineering schools already offer writing courses and classes designed to improve oral presentations. Still, based on the findings of the sociology of work practice I would suggest enhancement of the ***interactive social skills*** of engineering students by requiring them to work on customization processes as part of their undergraduate and graduate studies. These exercises, supported by industry through summer internships, will not only improve the engineering students' communication skill within the design team but will also require them to develop what Pacey (1990:146-7) calls a "***technological dialogue***", and to negotiate technical details with clients. A technological dialogue consists of the interactive exchange of technical details dealing with the adaptation of high-tech products to the specific needs of clients. As part of this efforts engineering students should learn how to manage a ***technological interview***, specifically structured to extract vital technological information about the client's application. Engineering courses that require students to confront the growing interdependencies between social and technical skills will support an emphasis on value-added processes and will improve the competitiveness of American firms operating in the high-technology sector.

Most engineers in the industrial era built their careers by moving into managerial positions. However, in the near future more engineers will find themselves making horizontal career moves into sales positions, where they will engage in customization work. These will be highly qualified engineers in their early career stages working as sales, field application and customer engineers. Sales positions and sales work enjoy a lower occupational status than engineering, and based on my own research many engineers find it hard to accept their role as frontline workers. More generally, the traditional boundaries between design, production and sales seem to be blurring with the shift from the sale of a product to the sales of a process. Engineers with a strong background need to be prepared to act as brokers, balancing the sometimes conflicting demands of their clients and their own design department; nor should they expect to be buffered from market exigencies in their R&D labs. Engineering schools might find ways to re-shape their graduates career expectations and to emphasize the technological complexity and challenge involved in managing customization processes under the sales and marketing department.

Studies comparing the work attitudes of scientists and of engineers (see Ritti, 1982) portray the former as "cosmopolitan", meaning more dedicated to their occupational community than to their employing organizations. The latter are described as more "local", meaning dedicated more to their employers than to their professional community. The local inclination of engineers is not surprising, given their long alliance with capitalists, their status as "trusted employees" (Whalley, 1986), their tendency to move into managerial positions, and the role they played in the creation of the management field at the turn of the $19^{th}$ century. The local values are part and parcel of engineering education, yet the changing realities of technical work call for the re-configuration of engineering as a viable occupational community whose boundaries transcend the employing organization.

What steps might engineering schools take to enhance ties among engineering graduates during school and after graduation? One proposal is to initiate design and customization projects across engineering schools.  In this way engineers will get a chance to increase their social capital, which might be utilized in the later stages of their careers. Also, where possible, customization projects should include foreign engineering schools, to expose the engineering graduates to the work realities in a globalized world and to emphasize the need to accept different styles of engineering practice. Industry also has an important role in enhancing ties among employed engineers and their occupational coomunity by adopting some of the policies existing, for example, in the bio-technology industry. Bio-tech firm encourage their scientists to collaborate with other scientists in academia or working for other firms; they likewise urge their scientists to present their work at scientific and applied conferences (see Oliver and Liebeskind, 1998).

One important finding of the review I set forth is that engineers today increasingly work under conditions of product ambiguity, compared with their counterparts 25 years ago. Regardless of the underlying reason (whether increased ambiguity is the product of the technological revolution we are currently experiencing and will pass with time, or whether the flexibility built into software is the cause of increased ambiguity) engineering schools should direct their efforts to enhancing the efficiency of working when an engineer is unable to determine clearly how a product will be used by the client. Stated differently, engineering schools should focus on managing and selling a process rather than a traditional product. Working under conditions of high ambiguity requires more independent thinking and creativity, and engineering schools might want to devise ways to improve these elements.

The challenge posed by globalization to engineering education has been widely acknowledged, yet many of the practical recommendations remain rather abstract. The rise of China and India as centers for design on top of manufacturing will pressure US-based engineering school to enhance the quality of training and the creativity of their graduates in an attempt to preserve the value-added aspects of engineering design. In addition, global customization processes will increase in quantity and complexity, and future US engineers should be trained to manage these complex endeavors. Better acquaintance with Chinese and Indian engineering practices and cultures through special courses and exchange programs will improve the chances of American engineers leading the global engineering market rather than becoming its casualties.

## References


ATTEWELL, P. (1990) What Is Skill? *Work and Occupations*, 17: 422-448.

ARMSTRONG, P. (1993) Professional Knowledge and Social Mobility: Postwar Changes in the Knowledge-base of Management Accounting. *Work, Employment and Society* 7(1): 1-21.

ARMSTRONG, P. (1986) Management Control Strategies and Inter-Professional Competition: the Cases of Accountancy and Personnel Management. In D. Knights and H. Willmott (Eds.), *Managing the Labour Process*, pp. 19-43. Aldershot: Gower.

AUTOR, D.H., KATZ, L.F. and KEARNEY, M.S. (2006) The polarization of the U.S. Labor Market. *NBER Working Paper* (January 2006).

BARKER, J.R. (1993) Tightening the Iron Cage: Concertive Control in Self-Managing Teams. *Administrative Science Quarterly* 38: 408-437.

BARLEY, S.R. (2005) What Sociologists Know (and Mostly Don't know) about Technical Work. In S. Ackroyd, R. Batt, P. Thompson and P. Tolbert (Eds.), *Handbook of Work and Organisation*, pp. 376-403. Oxford: Oxford University Press.

BARLEY, S.R. and BECHKY, B.A. (1994) In the Backrooms of Science: The Work of Technicians in Science Labs. *Work and Occupations* 21: 85-126.

BARLEY, S.R. and ORR, J. (1997) Introduction: The Neglected Workforce. In S.R. Barley and J. Orr (Eds.), *Between Craft and Science: Technical Work in U.S. Settings.* Ithaca and London: Cornell University Press.

BARLEY, S.R. and KUNDA, G. (2001) Bringing Work back In. *Organization Science* 12(1): 76-95.

BARLEY, S.R. and KUNDA, G. (2004) *Gurus, Hired Guns, and Warm Bodies: Itinerant Experts In a Knowledge Economy*. Princeton and Oxford: Princeton University Press

BARRETT, R. (2004) Working at Webboyz: An Analysis of Control over the Software Development Labour Process. *Work, Employment and Society* 38(4): 777-94.

BARRETT, R. (2001) Labouring Under an Illusion? The Labour Process of Software Development in the Australian Information Industry. *New Technology, Work and Employment* 16(1): 18-34.

BECHKY, A.B. (2006) Talking About Machines, Thick Description, and Knowledge Work. *Organization Studies*, 27(2): 1757-1768.

BECKER, S.G. (1975) *Human Capital.* New York:P National Bureau of Economic Research.

BELL, D. (1960) *The End of Ideology*. New York: Free Press.

BELL. D. (1979) The New Class: A Muddled Concept. *Society* 17: 15-23.

BELL, D. (1973) *The Coming of Post-Industrial Society*. New York: Basic Books.

BERTELS and SAVAGE (1998) Tough Questions on Knowledge Management. In G. von Krogh, J. Roos and D. Kleine (Eds.), *Knowing in Firms*, pp. 7-25. London: Sage.

BLAIR, T. (1998) The Third Way. London: Fabian Society.

BRINT, S. (1984) "New-Class" and Cumulative Trend Explanations of the Liberal Political Attitudes of Professionals. *American Journal of Sociology* 90(1): 30-71.

BRYNIN, M. (2002) Over-qualification in Employment. *Work, Employment and Society*, 16(4): 637-54.

CASPER, S. and MURRAY, F. (2005) Careers and Clusters: Analyzing the Career Network Dynamic of Biotechnology Clusters. *Journal of Engineering and Technology Management* 22: 51-74.

CASTELLS, M. (1996) *The Rise of the Network Society*. Oxford: Blackwell.

CASTELLS, M. and AOYAMA, Y. (1994) Paths towards the Informational Society: Employment Structure in G-7 Countries. *International Labor Review* 133(1): 5-33.

CAUSER, G. and JONES, C. (1996) Management and the Control of Technical Labour. *Work, Employment and Society* 10(1): 105-123.

COLLINS, M.H. (1993) The structure of knowledge'. *Social Research* 60/1: 95-116.

COLLINS, M.H. (1995) Humans, Machines and the Structure of Knowledge. *Stanford Humanities Review* 4/1: 67-84

CORTADA, J.W. (1998) Where Did Knowledge Workers Come From? In J. Cortada (Ed.), *Rise of the Knowledge Worker*, pp. 3-21. Oxford: Butterworth-Heinemann.

DARR, A. (2004) . Social Skills in Technical Sales Work". In Warhurst, Keep and Grugulis (eds.) *The Skills that Matter*. New York: Palgrave .

DARR, A.(2003) Control and Autonomy among Knowledge Workers in Sales: An Employee Perspective. *Employee Relations*, vol. 25(1): 31-42.

DARR, A. (2006) *Selling Technology: The Changing Shape of Sales in an Information Economy*. Ithaca: Cornell University Press.

DARR, A (2007) Service and Knowledge Elements in the Work of ERP Implementers. Working Paper.
DARR, A and SCARSELLETTA, M. (2002) Technicians, Clients and Professional Authority: Structured Interactions and Identity Formation in Technical Work." *New*

*Technology, Work and Employment*, 17, 1: 60-72.

DARR, A. *and* WARHURST, C. (2007) Assumptions, Assertions and the Need for Evidence: Debugging Debates about Knowledge Workers. Forthcoming in *Current Sociology*.

DEPARTMENT FOR TRADE AND INDUSTRY (DTI) (1998) *Our Competitive Future.* London: HMSO.

DESPRES, C. and *HILTROP*, J-M. (1995) Human Resource Management in the Knowledge Age: Current Practice and Perspectives on the Future. *Employee Relations* 17(1): 9-23.

DRUCKER, P. (1959) *Landmarks of Tomorrow.* New York: Harper & Brothers.

DRUCKER, P. (1978) *The Age of Discontinuity.* New York: Harper & Row.

DRUCKER, P. (1979) Managing the Knowledge Worker. *Modern Office Procedures* 24: 12-16.

EUROPEA COMMUNITIES (EC). (2004) Facing the Challenge. Luxembourg: Office for Official Publications of the European Communities.

GREEN, F. (2000) The Impact of Company Human Resource Policies on Social Skills: Implications for Training Sponsorship, Quit Rates and Efficiency Wages. *Scottish Journal of Political Economy*, 479(3): 251-72.

HECKER, D., E. (2005) Occupational Employment Projections to 2014. *Monthly Labor Review*, November: 70-101.
KIDDER, T. (1981) *The Soul of a New Machine*. Boston: Little, Brown.

KNOKE, D. (1999) Organizational Networks and Corporate Social Capital. In R. Leenders and S.M. Gabbay (eds.) *Corporate Social Capital and Liability*. Boston: Kluwer.

KUNDA, G. (1992) *Engineering Culture: Control and Commitment in a High-Tech Corporation*. Philadelphia: Temple University Press.

KREINER, K. and SCHULTZ, M. (1993) Informal Collaboration in R&D: The Formation of Networks Across Organizations. *Organization Studies*, 14(2): 189-209.

LATOUR, B. and WOOLGAR, S. (1979) *Laboratory Life*: *The Social Construction of Scientific Facts.* Beverly Hills: Sage.

LAVE, G. and WENGER, E. (1991) *Situated Learning: Legitimate Peripheral Participation.* Cambridge: Cambridge University Press.

LEIDNER, R. (1993) *Fast Food, Fast Talk: Service Work and the Routinization of Everyday Life.* Berkeley and London: University of California Press.

MANDT, E. (1978) Managing the Knowledge Worker of the Future. *Personnel Journal* 57(3): 138-141.

McKINLAY, A. (2002) The Limits of Knowledge Management. *New Technology, Work and Employment* 17(2): 76-88.

MCLOUGHLIN, I. and CLARK, J. (1994) *Technological Change at Work.* Buckingham & Philadelphia: Open University Press (2nd edition).

MILLER, B.D. (1977) How to Improve the Performance and Productivity of the Knowledge Worker. *Organizational Dynamics* 5(3): 62-80.

MILLS, C.W. (1951) *White Collar*. Oxford: Oxford University Press.

NATIONAL ACADEMY OF ENGINEERING. (2005) *Educating the Engineer of 2020: Adapting Engineering Education to the New Century.* Washington, DC: The National Academies Press.

NATIONAL ACADEMY OF ENGINEERING. (2004) The Engineer of 2020: Visions of *Engineering* in the New Century. Washington, DC: The National Academies Press.

NEWELL, S. ROBERTSON, M., SCARBROUGH, H. and SWAN, J. (2002) *Managing Knowledge Work.* London: Palgrave.

OECD (1994) *Jobs Study: Evidence and Explanations*. Paris: OECD.

OECD (2001) *Science, Technology and Industry Scoreboard: Towards a Knowledge-based Economy*. Paris: OECD.

OLIVER, L.A. and LIEBESKIND, J.P. (1998) Three Levels of Networking for Sourcing Intellectual Capital in Biotechnology. *Int. Studies of Management and Organizations* 27(4): 76-103.

ORR, J.E. (1990) Sharing Knowledge, Celebrating Identity: Community Memory in a Service Culture. In David Middleton and Derek Edwards (Eds.), *Collective Remembering*, pp. 169-189. London: Sage.

ORR, J.E. (1996) *Talking About Machines: An Ethnography of a Modern Job*. Ithaca and London: Cornell University Press.

PENTLAND T.B. (1991) Organizing Moves in Software Support Hot Lines. *Administrative Science Quarterly* 37/4: 527-548.

PINCH, J.T. and BIJKER, E.W. (1987) The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other'. In *The Social Construction of Technological Systems*. W.E. Bijker, E.C. Hughes, and T.J. Pinch (eds.), Cambridge, Mass: MIT Press, pp. 15-50..

PINE, J. B. (1993) Mass Customization. Boston: Harvard Business School Press.

REICH, R. (1993) *The Work of Nations*. London: Simon & Schuster.

SCARSELLETTA, M. (1997) The Infamous "Lab error": Education, Skill, and Quality in Medical Technicians' Work. In S.R. Barley and J.E. Orr (Eds.), *Between Craft and Science: Technical Work in U.S. Settings*, pp. 187-210. Ithaca: Cornell University Press.

SPENNER, I. K. (1980) Occupational Characterisics and Classification Systems: New Uses of the Dictionary of Occupational Titles. *Sociological Methods and Research*, 9: 239-264.

SPENNER, I. K. (1991) Skill: Meaning, Methods, and Measure. *Work and Occupations*, 17:399-421.

TOLBERT P.S. *and* STERN, R.N. (1991) Organizations of Professionals: Governance Structures in Large Law Firms. *Research in the Sociology of Organizations*, Vol. 8: 91-117.

U.S. Department of Labor, Bureau of Labor Statistics (1985) *Occupational* Employment *in Manufacturing Industries*. Washington, DC: U.S. Government Printing Office.

U.S. Department of Labor, Bureau of Labor Statistics (1988) *Occupational Employment in Manufacturing Industries.* Washington, DC: U.S. Government Printing Office.

U.S. *Department* of Labor, Bureau of Labor Statistics (1991) *Occupational Employment in Manufacturing Industries*. Washington, DC: U.S. Government Printing Office.

VAN MAANEN J. AND BAELEY, R.S. (1984) Occupational Communities: Culture and Control in Organizations. *Research in Organizational Behavior*, 6: 287-365.

VON HIPPEL, E. (1988) *The Sources of Innovation*. Oxford: Oxford University Press.

WHALLEY, P. (1986) *The Social Production of Technical Work*. Albany: State *University* of New York Press.

*WUTHNOW*, R. and SHRUM, W. (1983) Knowledge Workers as a new Class: Structural and Ideological Convergence among Professional-Technical Workers and Managers. *Work and Occupations*, 10:4

ZUBOFF, S. (1988) *In the Age of the Smart Machine*. NY: Basic Books.