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ABSTRACT

Between 1950 and 1988, the number of professional and technical workers increased by 282% while the labor force as a whole only increased by 94%. Most persons employed as technicians work on or with reputedly complex technologies. Most work at the empirical interface between a larger production process and the materials on which the process depends. At such interfaces, the technician's task involves the complementary processes of transformation and caretaking. In some occupations, technicians buffer other occupations from contact with the empirical phenomena over which the latter are reputed to have mastery. In other occupations, technicians function as brokers bridging the organization they serve and the larger technical community associated with the technology they oversee. In either case, technicians require both formal and contextual knowledge. In view of technicians' roles and knowledge requirements, effective educational programs for training technicians must impart contextual knowledge of a technical domain, practicing technicians must be involved in designing technician training programs, and conceptions of technical education must be broadened to include translation competency. Policymakers must direct resources to developing tools for timely exchange of information and development of communities of practice. (Contains 35 references.) (MN)

EQW WORKING PAPERS

What Do Technicians Do?

by

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"What Do Technicians Do?"
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Introduction

Twenty years ago Daniel Bell (1973) told of the coming of a postindustrial society in which the production of knowledge and services would eclipse the production of goods as a source of employment. Trends in the composition of the American labor force continue to vindicate Bell's vision (Block 1990; Barley 1991). The unskilled and semiskilled blue-collar labor force, which accounted for 28 percent of the working population in 1940, now represents less than 16 percent of all employed Americans. Only 3 percent of the population works on farms. In 1970, clerical employment accounted for 18 percent of the labor force but has since declined to 16 percent, largely because of office automation. Even the growth of managerial jobs has begun to level off in recent years because of corporate downsizing.

The decline of occupations spawned by the industrial revolution and the growth of bureaucracies contrasts sharply with the rise of occupations linked to the production of knowledge and services. Especially dramatic has been the expansion of the professional and technical workforce. Between 1950 and 1988 the number of professional and technical workers increased by 282 percent, a growth rate three times that of the entire labor force (94 percent). By 1988, professional and technical workers were tied with clericals and with operatives for the status of most prominent occupational category. One of four new jobs is now a professional or technical job. Forecasts indicate that by 2000, professional and technical occupations will have become the largest of all occupational sectors, representing 18 to 20 percent of the American labor force (Silvestri and Lukasiewicz 1989; Bishop and Carter 1991).

Although evidence of the increasing importance of technical work has been available since the 1960s, the shifting composition of the workforce has only recently attracted attention. The economic importance of scientific and technical education first became a topic of public concern in the mid-1980s with the appearance of several reports that said that American students were not performing as well in science and math as their counterparts in other nations (Johnston and Packer 1987). Employers, educators, and policymakers have since proposed several initiatives to enhance scientific and technical literacy and to prepare young people for higher-skilled, technical jobs

(Committee on Science and Technology 1986; Aerospace Education Foundation 1989; Committee on Science, Space and Technology 1991). Most of these initiatives emphasize formal education in science, math, and technology.

Given trends in the labor force, few would dispute the need to orient students and schools to the opportunities and demands of a postindustrial economy. Of particular importance are programs that target what Parnell (1985) called the "neglected majority," youth who currently pursue a general education curriculum in high school and who represent the most likely candidates for the expanding number of technicians' jobs. The task of designing programs for training technicians is severely hampered, however, by the fact that no segment of the labor force is less understood. Since World War II, social scientists have generated an enormous literature on blue-collar, clerical, managerial, and professional work. Yet, besides a handful of studies of engineering (e.g., Peltz and Andrews 1966; Allen 1977; Bailyn 1980; Whalley 1986; Bucciarelli 1988; Kunda 1991), we know next to nothing about technical work in general and even less about the work of technicians. There have been fewer than two dozen studies of technicians and most of these have yet to be published.

In lieu of detailed information on technicians' work, educators and policymakers have little choice but to rely on common-sense notions of what technicians do. However, common-sense notions sometimes prove misleading. For instance, the educational and policy literature routinely portrays technicians as "junior professionals" whose work requires a less rigorous, more "applied" version of the formal knowledge of a professional specialty. It is easy to see how such an image might arise. Many technicians work alongside physicians, scientists, and engineers. Yet, if the image of a "junior professional" is inaccurate, it may lead educators to develop curricula that are, at best, irrelevant and, at worst, a barrier to entry.

In 1991 researchers associated with the Program on Technology and Work at Cornell's School of Industrial and Labor Relations embarked on a five-year study to gather detailed information on technicians' work. Our strategy has been to conduct coordinated ethnographies of a range of technical occupations that can be used to specify the parameters and social organization of technicians' jobs. Each study in our portfolio focuses on a single occupation and entails extensive observation in work sites for 6 to 12 months. To date, we have completed investigations of emergency medical technicians (Nelsen and Barley 1992), science technicians (Barley and Bechky 1993), medical technologists (Scarselletta 1992), radiological technologists (Barley 1990), and scientific liaisons in the European Space Agency (Zabusky 1993). Studies of microcomputer support specialists, engineering technicians, and programmers are under way. We are about to launch studies of technical sales, software engineering, automobile repair, and technicians on factory floors.

This paper summarizes several preliminary observations that we believe warrant consideration by those charged with formulating educational policies and programs. The observations suggest that conceptualizing technicians as "junior professionals" misrepresents the technician's role. The notion of a "junior professional" carries at least two unwarranted connotations. First is the suggestion that technicians serve professionals as functionaries. Second is the suggestion that the professional's knowledge subsumes that of the technician. We have found instead that the division of labor between technicians and professionals is usually more collaborative (horizontal) than hierarchical (vertical) and that members of the two types of occupations command substantively different knowledge and skill. Even more problematic for the notion of a junior professional is the fact that many technicians work in contexts that are not tied to the activities of a profession. The discussion that follows begins with the nature of the technician's role, moves to the type of knowledge that technicians command, and ends by elaborating implications for the education of technicians.

Observations

The Technician's Role

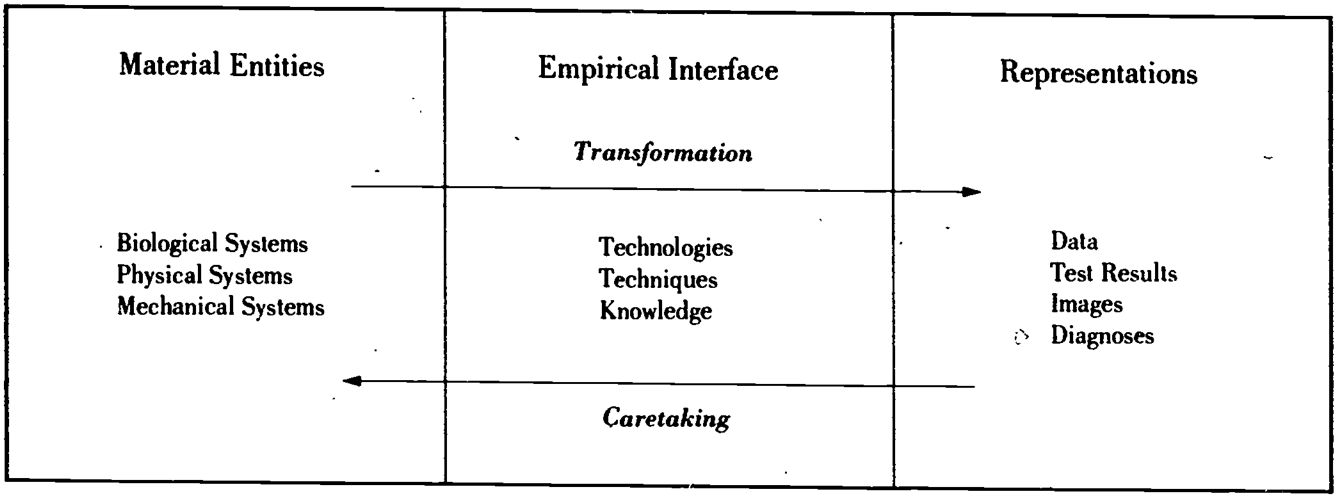
Overseeing an Empirical Interface. Most persons employed as technicians work on or with reputedly complex technologies or techniques. Most also work at the *empirical interface* between a larger production process and the materials on which the process depends. Depending on context, the relevant materials may be hardware, software, microorganisms, the human body, a manufacturing process, and a variety of other physical systems. The technician's task at the empirical interface involves two complementary processes: *transformation* and *caretaking*.

On one hand, technicians employ technologies and techniques to transform aspects of the material world into symbolic representations that can be used for other purposes. For instance, sonographers (Barley 1990), emergency medical technicians (Nelsen and Barley 1992), and medical technologists (Scarselletta 1992) produce images, counts, assays, and other data useful for medical diagnosis. Technicians in nuclear power plants (Hirschhorn 1984) and other automated facilities (Zuboff 1988) create and monitor flows of information on production systems. Science technicians reduce physical phenomena to data or "inscriptions" from which scientists construct arguments, papers, and grants (Latour and Woolgar 1979; Barley and Bechky 1993).

Yet, technicians do more than generate symbols and information. Most are also responsible for taking care of the physical entities they oversee. Technicians are charged with ensuring that machines, organisms, or other physical systems remain intact and in good working order. Caretaking often requires technicians to employ the representations they create. Emergency medical technicians perform medical interventions based on diagnoses they make at the site of an accident (Nelsen and Barley 1992). Technicians in biology labs employ the data they generate to husband organisms and monitor technologies (Barley and Bechky 1993). Microcomputer technicians use the results of tests and probes to alter the functioning of computer systems.

Figure 1 depicts the technician's activity at an empirical interface. Transformation and caretaking represent the *epistemic core* of a technician's job. In pursuing these activities technicians develop and use unique bodies of knowledge, information, and skill. Although the details of their work may vary, the general structure of the epistemic core is common to all technicians' jobs. The technician's

Figure 1
The Technician's Work at the Empirical Interface: The Epistemic Core



social role, however, varies according to how the epistemic core is articulated within a division of labor. Based on our research and the research of others, we submit that technicians' work is of at least two general types.

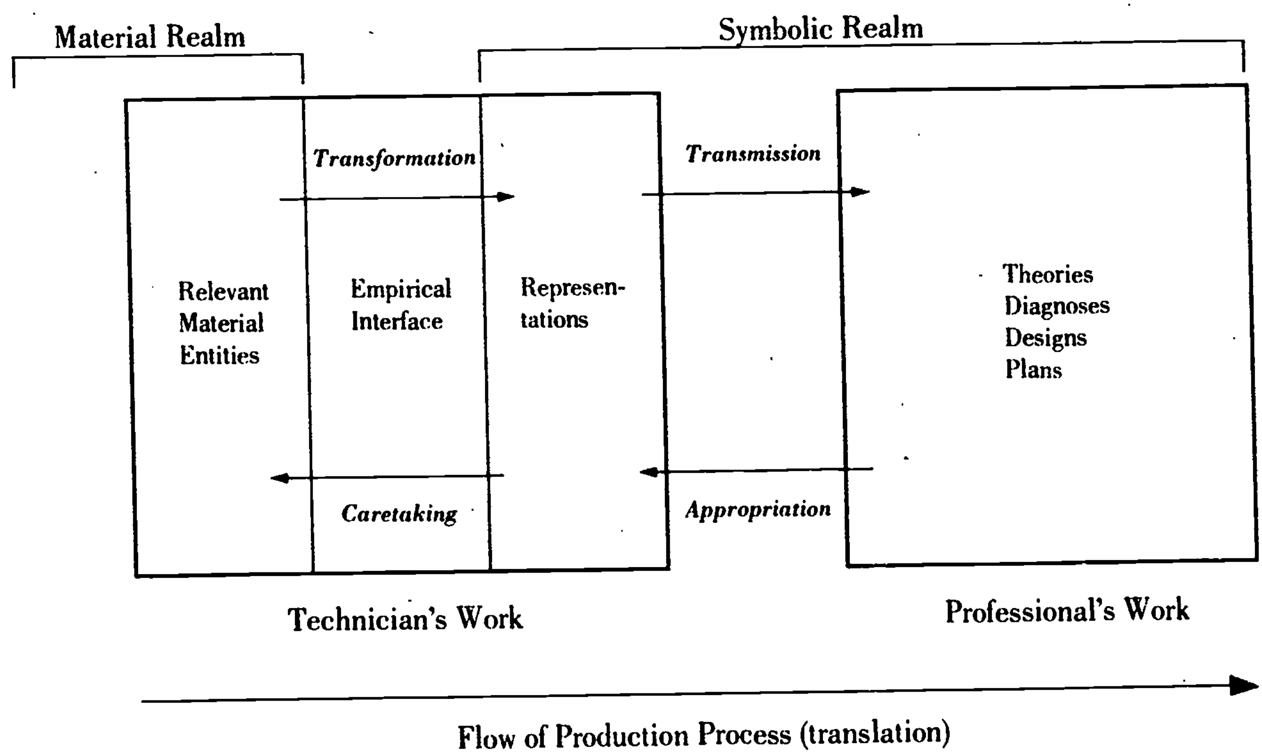
Buffers. Members of some technical occupations *buffer* other occupations from contact with the empirical phenomena over which the latter are reputed to have mastery. These technicians are usually positioned near the beginning of a *serially interdependent, occupational division of labor* such that the technician's "output" serves as "input" for the work of an occupation classed as a profession. Thus, technicians link a world of symbols, information, or theory to its empirical referents. Science technicians, radiological technologists, emergency medical technicians, and medical technologists are illustrative of technicians who serve as buffers. Because science technicians operate lab equipment, conduct experiments, and generate data, they, rather than scientists, usually preside over science's encounters with the physical world. As a result, science technicians shield scientists from the vagaries of empirical encounters (Barley and Bechky 1993). By stabilizing patients at the scene of an accident, emergency medical technicians similarly relieve physicians and nurses of the need to do triage (Nelsen and Barley 1992). Radiological technologists and medical technicians distance radiologists and pathologists from encounters with patients or their bodily tissues and fluids (Barley 1984; Scarselletta 1992).

Because the technicians and professionals speak much the same language, buffers usually *transmit* the representations they create directly to the professional. The professional then employs the technicians' representations in his or her own work. For instance, emergency room physicians use the EMTs' initial diagnoses to begin treatment. Radiologists develop differential diagnoses based on the sonographer's images and even the sonographer's interpretations (Barley 1990). Scientists often employ data assembled by technicians without further analysis.

Membership in a common speech community affects the technician's work as well. Technicians who serve as buffers usually draw on or *appropriate* the professionals' theories, plans, diagnoses, or designs to inform their work at the empirical interface. To stabilize patients, EMTs make diagnoses that require them to be conversant with theories of disease. Sonographers must understand pathological processes to capture diagnostically useful images. Technicians in biology labs employ elements of scientific theory to manage enigmas that arise during laboratory procedures (Barley and Bechky 1993).

Figure 2 depicts the structural position of a technician who serves as a buffer. The central dynamic of the production process (which moves from left to right in the figure) is one of *translation*. Technicians reduce physical phenomena to symbolic representations and then transmit those representations to professionals. Two points are salient. First, the technician stands between the professional and the empirical phenomena that grounds the professional's work. Second, because the two occupations share a speech community, the linguistic and cultural (and, hence, in Figure 2, the spatial) distance between the

Figure 2
Technicians as Buffers



two groups is minimized. Both parties share a social world, be it the world of a medical specialty, a scientific discipline, or another professional field.

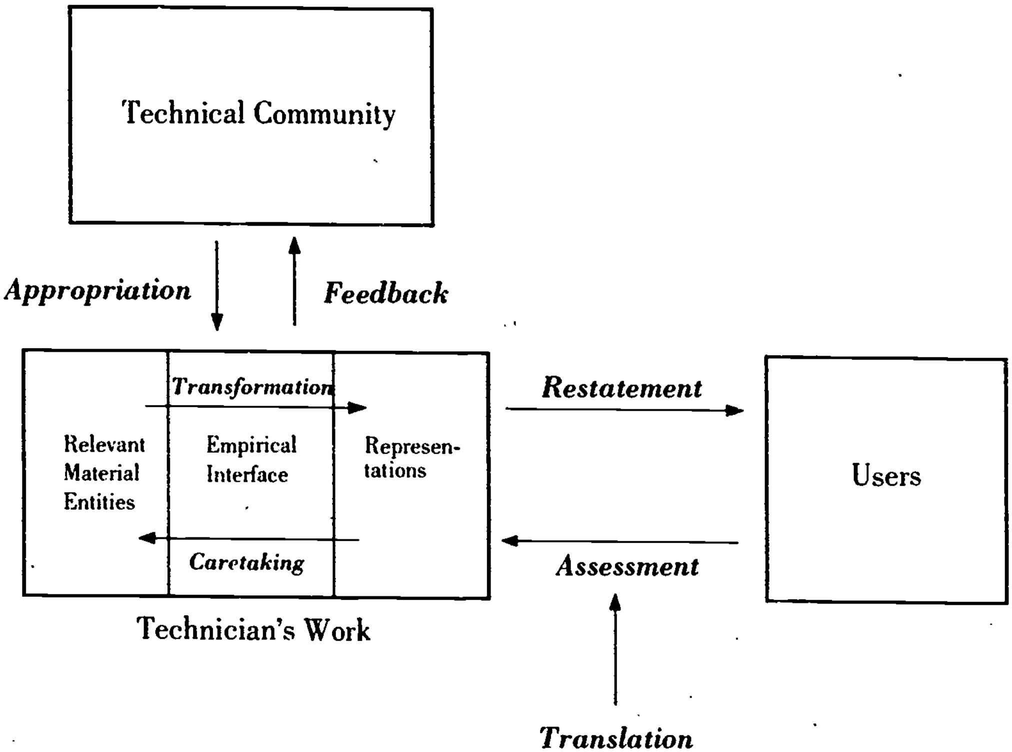
Brokers. Joint membership in a social world is uncharacteristic of a second group of technical occupations. These technicians work in what is best described as an *organizational division of labor*. Moreover, because the technician's output is often not *substantively relevant* to those who depend on their work, the division of labor is not serially interdependent. Others do not depend on specific products of the technician's work. Instead the technicians are responsible for creating *general conditions* necessary for the work of others. Technicians of this sort typically oversee some aspect of the technical infrastructure on which a production system rests. Copier repair technicians (Orr, forthcoming), microcomputer technicians (Barley and Zabusky, in progress), network administrators, programmers (Kuhn 1989), software support specialists (Pentland 1991), systems analysts, and most other computer technicians are illustrative.

The epistemic core of the second type of occupation is identical to the first. To manage a technological infrastructure, a technician must create symbolic representations of the state of the technology and then maintain or alter the technology based on the representations. However, the technician's position in the production system differs from that of a buffer. Programmers, microcomputer technicians, copier repair technicians, and network administrators are usually "foreigners" in the work site. They belong to an occupational community that exists largely outside the organization where they work and their expertise differs radically from the expertise of those whom they serve. Hence, although such technicians may buffer others from the intricacies of a technology, their role is essentially that of a *broker*.

Brokers bridge two communities: the organization they serve (either permanently or temporarily) and the larger technical community associated with the technology they oversee. Technicians' work entails adapting the technical community's knowledge and products to the contextually specific needs of users, clients, or customers. Orr (forthcoming) has documented how copier repair technicians mediate between the local practices of organizations that lease copiers and the engineering community that designs them. As a result, copier technicians develop a unique body of knowledge. Barley and Zabusky (in progress) have found a similar phenomenon among microcomputer technicians and "in-house" programmers who develop databases for their employers. Microcomputer technicians are charged with assembling, modifying, and repairing workstations and networks used by employees of an organization. The technicians continually scan the technical community for relevant information while simultaneously communicating with users about the organization's needs. The computer systems they construct are local syntheses of the constraints and possibilities defined by the intersection of the two worlds. Software developed by in-house programmers exhibit the same hybrid quality. Brokers therefore mold technological feasibilities into local realities.

Figure 3 illustrates schematically the structural position of a broker. Brokers sit between a technical community and a community of users whose work depends on the systems that the brokers oversee. The broker's relationship to the community of users is twofold. On one hand, brokers assess the users' needs and then develop systems that meet those needs via their caretaking function. On the other hand, if the system is to perform optimally, brokers must also educate users about the system's functioning, features, and limitations. To the degree that technicians and users inhabit different social worlds, education involves *restating* technical information in a

Figure 3
Technicians as Brokers



form that users can comprehend and use. *Restatement* and *assessment* therefore require brokers to engage in considerable translation. Not only must users' needs be formulated as technical parameters, but also technical parameters must be made meaningful to people with little technical background. Unlike technicians who serve as buffers, brokers must therefore speak the language of two communities.

The brokers' relationship to the technical community is less complex than their relationship to the user community in that technicians usually identify with the technical community's culture. In some settings, such as software support (Pentland 1991), the broker's interaction with members of the technical community approximates a buffering relationship. In other instances, the relation is more attenuated. Microcomputer technicians are a case in point. The technical community relevant to microcomputer support is populated by vendors of hardware, software, and technical services. Technicians monitor the technical community for "state-of-the-art" information and for solutions to actual or potential problems. Microcomputer technicians read continuously and consult with other technicians and with vendors when opportunities arise. Although they appropriate technology and knowledge from the technical community, they feed back little information except when they encounter bugs or are consulted by vendors.

The Nature of Technicians' Knowledge and Skill

Formal Knowledge. Commentaries on the shortage of technicians routinely conclude that the United States should begin coaxing a broader segment of the population to pursue formal training in science and technology. The rhetoric of employers likewise privileges formal knowledge and credentials. Consequently, most schemes for increasing the number of technical workers emphasize instruction in science, engineering, and technology. We have found, however, that the perceived importance of credentials contrasts sharply with the experience and opinions of technicians themselves.

Outside medicine, where laws mandate credentials, many technicians possess no formal technical training. Even in science and engineering, where credentials are customary, one finds a significant number of technical workers without advanced degrees. Barley and Bechky (1993) report that among the university-based science technicians they studied, holding rank constant, a quarter possessed at least a master's degree, but another quarter had no more than a high school diploma. Researchers report similar findings among engineers. Studies suggest that between 20 and 30 percent of all engineers in the United States lack a bachelor's degree in engineering and many have no more than a high school diploma (Zussman 1985). The percentage of engineers without degrees is even higher in Britain (Whalley 1986). Preliminary evidence suggests that many engineering technicians also lack advanced degrees.

When credentials are neither mandated nor customary, even fewer technicians are credentialed. Computer-related occupations are especially instructive in this regard. Barley and Zabusky (in progress) found that 50 percent of the microcomputer technicians and in-house programmers they studied have no formal technical training. Microcomputer technicians exhibit a variety of educational backgrounds. Some have advanced degrees in the social sciences and the humanities, some come from a computer science background, while others have but a high school degree. Yet, all do roughly similar work.

Perhaps more troublesome for advocates of credentialling is the fact that technicians with technical degrees also claim they use little of what they learned in school. Students of engineering report that engineers are particularly cynical about the relevance of their schooling (Zussman 1985; Whalley 1986). Radiological technologists, science technicians, medical technologists, programmers, microcomputer technicians, and emergency medical technicians voice similar sentiments. In fact, we have yet to encounter a technician willing to testify to the importance of the content he or she learned in school.

This is not to say that technicians view their formal education as totally irrelevant. Technicians often claim that they think more "rigorously" or "logically" about problems because of their education (Zussman 1985). When solving problems, technicians also occasionally employ heuristics and other bits of knowledge that can be traced to courses in technical subjects (Barley and Bechky 1993). The technician's devaluing of formal education is therefore best interpreted as a sign that they subscribe to a theory of learning that differs from that of most educators. Educators often portray courses in formal theory as a necessary platform for understanding the details of practice. Technicians believe the converse: that *practice provides the platform necessary for making sense of theory.* Consider, for example, the philosophy of an accomplished research support specialist with a master's degree in cell biology who routinely trains technicians in cell culture techniques:

> First I let them observe me do it. Then I let them do it. Finally, I give them materials to read. It's of little use to read about a process before you do it

because the papers are too confusing. It works better if you see it first and then read. . . . Reading becomes more helpful once you have an idea of what the words *really* mean.

Regardless of occupation, all technicians appear to value experience and practical understanding over formal knowledge. In fact, in our studies the only technicians who have made positive claims about their schooling were those whose training involved hands-on practice. The testimony of a computer technician with an associate's degree in information systems is typical:

> What do I use from my schooling? Well, the typing class I took was really good. From my computer classes, not too much. A little bit from the system design course. But in my second year [at college], I became a computer proctor. I watched over the computer lab and got to be good friends with the man who was in charge of tech support for the campus. So my job actually moved into working with him instead of being a proctor in the computer room. He and I would go around campus fixing and upgrading computers and running cable. So that's where I got *all* my background.

Contextual Knowledge. Why do technicians universally value experience more highly than formal training? In part, experiential knowledge is more important because technologies and techniques change so quickly that by the time information filters into a classroom it is already out of date. Moreover, in applied settings knowledge is only relevant in the context of a problem. Since problems usually have aspects that cannot be anticipated, technicians find that they have to search for information specific to the problem at hand. Thus, as technicians suggest, problem-solving skills are the most one can expect from a technical education. Yet, the most important reason for valuing experience is to be found in what the term connotes for the technician.

By "experience" most technicians do not simply mean an extended period of practice. Instead, "experience" serves as a shorthand for *contextual knowledge* of materials and techniques. Contextual knowledge entails a variety of skills and abilities tied to the specifics of the technician's work. Practice is merely the path by which most technicians develop contextual knowledge. Technicians argue that although contextual knowledge is critical for successful practice, training programs provide few opportunities to acquire it. The following remarks by a sonographer on the educational establishment's tendency to elevate theoretical over contextual knowledge are remarkable only for their passion:

> On the registry they want to know such things as "what kind of tissue is the pancreas composed of?" How the hell do I know and what difference does it make? Pancreatic tissue. Who the hell are these people? I'll go one-on-one with anybody in scanning ability. . . . I know my anatomy cold. What's more, I know my way around the body three-dimensionally. Anybody can read a cross-sectional view, but you have to be able to turn it around like you were looking from the front and be able to locate the problem. That's not easy and most of the kids coming out of the programs can't do that. . . . A lot of the kids coming out are incompetent. We had a student out here. She could sit down and go through charts and read pathology reports and tell you what they meant. I couldn't do that. She could draw you a picture of the vascular system, but she couldn't find it in the body. They're just not properly trained. Experience is the best teacher. . . .

Here, the sonographer speaks of a critical skill that the curriculum's designers did not apparently recognize. To produce viable ultrasound images one must visualize the body in three dimensions although the images that one interprets are two-dimensional. Without this ability one cannot position the transducer to acquire a diagnostically useful set of images. Most technicians tell similar stories about crucial skills that are ignored by formal education largely because educators do not recognize their importance. Therefore, almost all technicians claim that they had to acquire such contextual knowledge on the job.

One must be careful in interpreting what technicians mean by on-the-job training. Most employers do not orchestrate the training of new technicians. Nor do they usually assign mentors to the newly hired. Instead, technicians appear to gain contextual knowledge by solving problems, by informal coaching, and perhaps most importantly by listening to "war stories" that encode lessons learned by colleagues (Orr, forthcoming). Members of every technical occupation we have studied partake of a "community-of-practice" composed of others with similar interests, responsibilities, and skills (Lave and Wenger 1992). These communities make use of a variety of channels for communicating information to their members. Face-to-face contacts are most pervasive. Technicians not only discuss problems and discoveries with their immediate colleagues, they are usually linked to technicians at other sites who can serve as informal consultants. Technicians therefore serve as repositories of contextual knowledge that is disseminated orally through networks. Vendors of equipment and supplies also function as crucial conduits of information. Some occupations, such as medical and radiological technology, are sufficiently well organized to have their own journals. Others use less "professional" media. For instance, microcomputer technicians scour commercial magazines aimed at "high end" computer users. Internet has also begun to function as a source of highly specialized information for microcomputer technicians and technicians in science labs.

Although, by definition, the precise content of contextual knowledge varies from occupation to occupation, broad commonalities exist. Most important is the ability to make sense of subtle differences in the appearance of materials and the behavior of techniques or instruments. Accomplished technicians see signs and codes where novices, and even professionals, see no information at all. For example, bench talk in science laboratories routinely revolves around the relevance of colors, shapes, patterns, sounds, and smells (Barley and Bechky 1993). Technicians use such information to decide whether experiments are progressing properly and to begin corrective action when events go awry. Sonographers distinguish between findings and artifacts by noting subtle differences in the shading of images and by attending to a variety of other cues such as the presence of scars on a patient's body. Microcomputer technicians often troubleshoot problems by attending to the sequence in which error messages occur while ignoring the messages' standard denotations. The meaning of a sequence of error messages is almost never discussed in technical documentation.

Sensory-motor skills are a second general component of contextual knowledge. Science technicians speak of "having a feel" for one's instruments, materials, and techniques. Although the idiom is sometimes synonymous with simple familiarity, technicians use the phase most often to refer to tactile skills or "ways of the hand" (Harper 1987). Cell culture specialists, for instance, warn trainees against "touching the cells wrong." Improper touching encompasses a variety of acts including pushing tissue too forcefully through screens designed to separate cells or pipetting directly into a test tube containing a cell colony.

Contextual knowledge encompasses an encyclopedia of heuristics or rules-of-thumb. Members of every technical occupation we have studied routinely recite heuristics to themselves and each other during their work. In fact, we have begun to wonder if talking to oneself is not actually critical for effective tech: ıcal problem solving. Finally, contextual knowledge usually encompasses adherence to a work style deemed crucial for avoiding the type of mistakes that occur in a particular technical context. For instance, being an accomplished science technician is nearly equivalent with demonstrating an almost obsessive concern for orderliness, cleanliness, reflexiveness, and documentation (Barley and Bechky 1993).

Technician as Cutpoint

The technician's mediating position in a division of labor and the importance of contextual knowledge account for a third observation regarding the work of technicians. Although other people may have considerable theoretical knowledge of the materials that technicians oversee, only technicians are positioned to develop a contextual understanding of materials and technologies because they serve as buffers and brokers. It is therefore the technicians' contextual knowledge rather than their formal knowledge that represents their substantive expertise. To the degree that contextual knowledge is necessary for the smooth functioning of a production system, the technician becomes, in the language of network analysis, a cutpoint, marking the critical connection of the whole: remove the technician and the entire system collapses.

In every technical setting we studied we found clear evidence that technicians are vital precisely because their contextual understanding is pivotal. Even scientists admit that without technicians lab work would stop because scientists do not possess the contextual knowledge necessary for empirical activities. In fact, most graduate students and postdoctoral fellows learn empirical procedures from technicians. The comments of the director of a monoclonal lab are representative:

> I did tissue culture for six years and was pretty good at it. Fifteen years ago, I knew the state of the art. But now, I don't know what they are using to wipe down the incubator. I have no hands-on knowledge of the cells. Sally (a research support specialist) can tell immediately if the cells are happy, from all the hours she spends looking at them. This is where the art comes in. It isn't mystery or mysticism, just the things that you don't consciously know—they are at the edge of your consciousness. Subtle things. A tech will say, "this doesn't look quite right." No one ever tells you these things, they aren't written down in books. Thinking, aware people develop gut knowledge, a sense of the wellness of the system. I have seen lab directors ruin their lab by giving orders to an RSS [research support specialist] or a tech who should be an RSS. A month later, the tech is looking for a new job and the director is left holding the bag.

Further evidence for the pivotal importance of the technician's knowledge can be found in those instances where labs attempt to duplicate each other's work. Although monoclonal techniques are supposedly well-documented by protocols and scientific papers, when one lab wishes to replicate another lab's cell line, it is usually necessary for technicians from the second lab to train technicians from the first (Cambrosio and Keating 1988). Collins observed a similar phenomenon in his study of technicians in physics labs (Collins 1974).

Under certain conditions, microcomputer technicians also become cutpoints in a production system, especially when computers are networked. When a network "goes down" an entire organization may be unable to work. Generally, it is impossible for outside technicians to effect repairs in a timely manner. The reason is that the technicians who constructed the network have acquired contextual knowledge of its idiosyncrasies that are opaque to technicians who have not worked with the network. In fact, Barley and Zabusky (in progress) observed that the use of outside technicians and computer consultants actually increases the odds of a malfunction. In lieu of relevant contextual knowledge, such individuals are likely to make modifications that trigger adverse interaction effects.

Implications for Policy

The foregoing observations challenge the prevalent image of a technician as a "junior professional," because they suggest that technicians are not mere adjuncts to an existing occupation. Instead, technicians are members of unique occupations with their own bodies of knowledge. Because this knowledge is largely contextual and because contextual knowledge is learned *in situ*, the technician's knowledge is not a subset of the knowledge commanded by another occupation. Furthermore, although technicians may have status incommensurate with their importance, it is not because they serve as functionaries in a vertical division of labor (Barley 1991; Barley and Bechky 1993). If accurate, these observations suggest at least four potential policy implications.

First, **effective educational programs for training technicians must impart contextual knowledge of a technical domain.** If one takes the technician's perspective seriously, hands-on experience must become integral to the education of the technical labor force. Apprenticeships and internships are ways of providing such experience. However, neither should be viewed as an adjunct to classroom instruction. Instead, classroom instruction might more appropriately be viewed as an adjunct to apprenticeship. If formal knowledge becomes relevant for technicians only in the context of practice, then it behooves educators to design curricula that tailor formal instruction to the exigencies of practice rather than the reverse. Apprenticeships and other hands-on experiences will not be maximally effective if approached as elaborate demonstrations to support theoretical points.

Second, **practicing technicians must be involved in designing training programs.** Unless educators and policymakers are themselves technicians (which, of course, most are not), they will be ignorant of the contextual knowledge that technicians require. Our observations imply that persons ignorant of the demands of practice do not usually design adequate training. Although an educator's knowledge of pedagogical tactics is useful for structuring the delivery of knowledge, it is important to recognize that the educator's expertise does not encompass the content of technical work. The same is true of professionals with whom some technicians interact. Policy makers must therefore be particularly alert not to confuse knowledge relevant for one occupation with knowledge relevant for another. Recognizing that technicians are themselves experts in the content of their work will lessen the risk of designing irrelevant curricula.

Third, **conceptions of technical education must be broadened to include translation competency.** Because technicians serve as buffers and brokers in a division of labor, a significant component of their work requires an ability to translate across the boundaries of social worlds. This skill is particularly crucial for technicians who work as brokers. Brokers must be able to assess the needs of users and articulate technical issues in a language that laypersons can understand. Not only are general communication skills required but also the ability to think of one's work and the work of others in systemic terms. The notion of translation is also useful for reexamining the role that formal theory plays in the education of technicians. Historically, technicians have been taught scientific, technical, or medical theory under the presumption that such knowledge provides a background crucial for the epistemic core of the technician's work. Although this perspective has merit, it may be that theoretical knowledge is most useful for enabling technicians to communicate effectively with the professionals with whom they interact. This possibility casts a different light on the relevance of formal knowledge and, by extension, the way in which such knowledge is taught.

Finally, since technical knowledge changes so rapidly, technical work demands continual learning and access to new information. Since relevant technical knowledge is usually bound to the particulars of a problem, critical information is difficult to systematize. For this reason, technical knowledge is generally spread informally and often orally through a community or network of practitioners. **Policy makers should therefore direct resources to the development of tools for the timely exchange of information and the development of communities of practice.** In particular, funds could be used to develop and maintain on-line databases indexed by terms that technicians use when solving problems. Resources might also be spent to facilitate the formation of the guild-like organizations that have proven so effective in spreading knowledge of techniques among craftspersons and professionals. Such approaches would recognize that from a policy perspective the community-of-practice is potentially a more relevant unit of analysis than the individual practitioner.

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