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LOCAL KNOWLEDGE SYSTEMS IN ADVANCED TECHNOLOGY ORGANIZATIONS

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Technology and structure are two fundamental dimensions of formal organization and an understanding of their relationship is crucial to the successful management of advanced technology firms. Research on the technology-structure interface has been concerned primarily with the possibility of causal relationships between the formal aspects of technology and structure; that is, the consciously planned and deliberately executed input-output flows that constitute formal technology and the arrangements of people and subunits that comprise formal structure within an organization (Fry, 1982). Less frequently, such research has considered the informal aspects of technology and structure; that is, the relationship between unplanned and spontaneous organizational processes and human interactions (see for examples Burawoy, 1979; Vaverek, 1987).

Technology has both a formal and an informal component, and the informal component (referred to herein as *local knowledge*) is a by-product of interaction between formal technology and informal organization (see Figure 1). Local knowledge is created by informal work groups in response to technological capabilities and limitations that were not envisioned by the designers of technology, but which emerge and command attention under conditions of actual use. To the extent that informal knowledge systems reflect both the inherent potential and the limitations of formal technology, it is argued here that local knowledge is shaped in important ways by a technological imperative—an imperative mediated by the creative problem-solving actions of informal social organization.

This chapter extends earlier work on the content and structure of informal knowledge systems in traditional manufacturing organizations by suggesting that local knowledge takes on a special character at advanced technology work sites (defined here as bounded work domains associated with advanced technology processes and/or products that are key to an organization's competitive position). The special characteristics of local knowledge systems at such sites include a distributed (i.e., widespread network) structure, creative expansion over time, and a content that includes information pertaining to systemic interrelationships. These characteristics both accommodate and reflect the special character of advanced technological processes and/or products. The chapter argues that local knowledge systems are an integral part of organizational technology and key contributors to productivity in advanced technology organizations. Managers in such organizations are advised to map the location of local knowledge systems and preserve their integrity in planning for organizational and/or technological change.

Many of the studies cited in this chapter are drawn from the tradition of ethnographic research; that is, empirical inquiry whose aim is understanding and interpreting behavior across systems of meaning (i.e., cultures). Most frequently, such ethnographic research has involved direct observation of behavior in natural field settings. Because local knowledge is informal, and oftentimes illicit, it has proven resistant to more structured data acquisition strategies and thus better suited to qualitative research in the ethnographic tradition. The relative paucity of empirical studies focusing on local knowledge systems in advanced technology organizations, however, means that the propositions set forth in this chapter must be considered tentative and preliminary.

DEFINING AND CHARACTERIZING LOCAL KNOWLEDGE

For purposes of this chapter, *local knowledge* is defined as a complex system of shared information, including abstract models of reality and methods of problem-solving related to technology, which is not formalized but is created spontaneously among work group members, and is used by group members to support the performance of work tasks.[1] The word *local* in this context is used to indicate that the knowledge is localized (i.e., contained) within an organizational subunit or system of subunits whose boundaries can be specified. Local knowledge is learned and shared by group members, and is transmitted to new members through informal communication networks whose structure can be mapped by social network analysis.

The Neoclassical Tradition

The existence of local knowledge systems and their effects on production first were hinted at indirectly in classic observational studies of workforce behavior in traditional manufacturing settings. In the Hawthorne experiments, Mayo's colleagues noted that some workers in the Bank Wiring Observation Room were able to achieve extremely high work speeds—speeds that seemed to defy what was possible by formal engineering standards (Roethlisberger & Dickson, 1939) Later, Roy (1952, 1954, 1958) showed that high speeds derived in part from illicit procedures used by machine operators to "make out" on piecework (i.e., produce a large number of pieces on some jobs, while restricting output on others). Working as a radial drill operator in the machine shop of a steel processing plant, Roy discovered that workers knew informal procedures and techniques that could be used to embellish or streamline machine operations before and after time-study ratings. Roy focused his attention primarily on illicit manipulation of company regulations as a means of increasing production speed. He found, for example, that workers sequestered main set-ups (i.e., basic tools needed to perform a range of jobs) under their work benches (rather than turning them in according to company regulations) in order to save set-up time on new jobs (Roy, 1954). More recent studies in the neoclassical tradition show that factory workers also perform illicit manipulations on machines themselves in order to boost work speeds. For example, Shapiro-Perl (1979) found that workers in a costume jewelry shop streamlined production by piling and processing together certain jewelry components in order to attain high volume production. Lamphere (1979) similarly discovered that individual workers in the apparel industry invented special sewing tricks that enabled them to increase production (and which they also taught to work trainees).

Unfortunately, none of the observational studies cited above nor others conducted during the 1940s and 1950s (e.g., Gouldner, 1954; Homans, 1953; Whyte, 1948) provide a detailed description or analysis of the informal knowledge base that mediates human interaction with the labor process. The focus of industrial sociology and anthropology traditionally has been the informal social relations of production—not the informal knowledge base that both underlies, and results from, social and technical relations at the work place. As a result of researchers' overriding interest in social relations, the informal aspects of production generally have been couched in social terms. Most typically, informal work procedures have been viewed as an extension of the informal work group's social control over production, with their function tied specifically to the promotion of internal group cohesion (see Blau & Scott, 1962). The effects of such procedures on production have been characterized generally as running counter to management's productivity objectives (see for discussion Albrecht & Goldman, 1985).

Kusterer's Characterization

One of the first (and most detailed) explicit conceptualizations of informal working knowledge (referred to herein as local knowledge) was given by Kusterer (1978), who conducted case studies of informal technical know-how at various work sites. Kusterer's data collection procedures includes both structured and semi-structured interviews, as well as direct field observation. From his early experience as a printer, Kusterer became convinced that the cognitive apparatus of skilled craftspeople includes knowledge paradigms (in Kuhn's [1970] sense) that organize their perception of work tasks and behavior on the job. Further, Kusterer believed that in the practice of work, skilled craftspeople function much as scientists—solving problems, acquiring knowledge and pushing at the frontiers of their paradigms—all in an informal fashion. Kusterer wanted to determine whether knowledge paradigms exist for all forms of work, regardless of skill level. Thus, he chose for his study occupations requiring relatively low levels of skill.

In Kusterer's (1978) study of the paper cone fabricating department in a traditional manufacturing firm, the labor process was highly mechanized and jobs had been divided into the lowest skill levels possible. Of the five job categories established to handle production, machine operators were the most deskilled (in Braverman's [1974] sense). Thus, Kusterer chose that job group for the focus of his work.

Apart from the formal knowledge acquired by machine operators during their brief training periods (i.e., knowledge related to basic work procedures, safety and quality standards, and company rules), Kusterer identified four types of supplementary knowledge—informal techniques and procedures needed to solve problems related to work performance. Each of these four types are named and described briefly below:[2]

1. *Knowledge about Materials.* Information pertaining to material defects and their impact on machine operations, and informal procedures designed to compensate for such defects (e.g., hand-finishing of materials in an otherwise automated process, using illegal [and unsafe] cleaning methods while machines were in operation).
2. *Knowledge about Machines.* Information pertaining to general machine failures and the idiosyncrasies of particular machines, and informal procedures designed to prevent failure or affect adjustments that improve productivity (e.g., using machine operators' own tools to make nonstandard alterations of machinery).[3]
3. *Knowledge about Quality Standards.* Information pertaining to several different (and partially contradictory) sets of quality standards (including standards used by inspectors, managers, customers and the work group itself), and the appropriate use of such standards to achieve various production objectives.
4. *Knowledge about the Work Community.* Information pertaining to the social values and norms held by members of other job categories, and the appropriate adoption of such values and norms to enlist aid from members of these other groups (e.g., nurturing an image of competence to encourage aid from mechanics).

The content of these four categories suggests that local knowledge systems are highly focused and selective, relating directly to workers' experiences with technology and containing both technical and social concepts needed to complete specific jobs. Based on his data, Kusterer (1978) suggests that local knowledge systems are most likely to develop around work phenomena that display a capacity for variance (i.e., error or discrepancy), occur with reasonable frequency (i.e., are neither constant, nor rare), and affect the performance of individual work tasks. Given these conditions, it seems likely that opportunities for the creation of local knowledge will vary directly with the number of productive functions assigned to each job (since a larger number of functions should display a larger number of variances). Further, such opportunities should vary with the degree of routinization that has been designed into each job function (since a high degree of routinization is typically associated with a lower degree of variance). In general, therefore, bodies of local knowledge should be more extensive where job functions are more complex and less routinized. It is possible, however, to imagine fairly extensive bodies of local knowledge developing in situations where simpler, more routinized jobs are associated with antiquated machinery and/or defective materials (as in Kusterer's cone fabricating department).

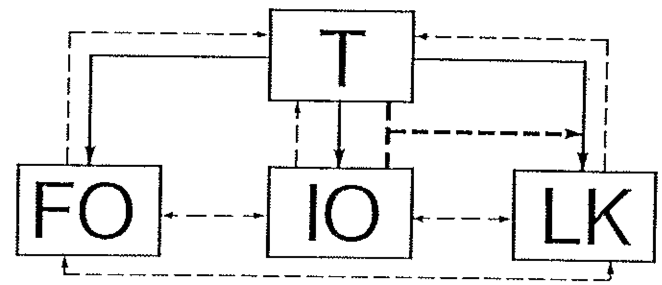
LOCAL KNOWLEDGE: A TECHNOLOGICAL IMPERATIVE?

Kusterer's (1978) pioneering work both confirms and extends the portrait of informal work procedures drawn by neoclassical scholars. Confirmation is provided for the neoclassical view of informal procedures as spontaneous, cooperative activities that enhance work group cohesion (and, in Kusterer's view, reduce alienation). Additionally, evidence is marshalled to support the premise that informal work procedures are illicit or underground phenomena (i.e., they are hidden from management). In the cone fabricating department and among other occupational groups studied by Kusterer, the creation and use of local knowledge systems often required work groups to violate formal job descriptions, make unscheduled alterations of machinery, engage in unsafe maintenance practices and ignore an assortment of corporate rules and regulations concerning material handling.

Even more importantly, however, Kusterer's work shows that informal work groups both affect technology through social means of control, *and* interact creatively with technology—discovering its hidden potential and coping with its emergent limitations in ways that generate informal bodies of knowledge related to technology. Indeed, from Kusterer's research we see that bodies of informal knowledge develop directly in response to gaps or inadequacies in formal bodies of knowledge pertaining to technology. This argument is elaborated as follows.

We know that designers of formal technology (whether material or social) typically cannot predict exactly how a given piece of technology will perform on the shop floor or office environment (Doutt, 1959; Tornatzky, Eveland, Boylan, Hetzner, Johnson, Roitman, & Schneider, 1982; Tornatzky & Fleischer, 1990). The designers may not know, for example, all of the ways that the technology can fail (e.g., when the technology is antiquated or is interacting with defective material). They also may not know all of the techniques that can be used to prevent or correct failure, or to otherwise maximize production under high pressure conditions. As a result of these gaps in formal bodies of knowledge, the formal training or documentation which accompanies technology often is inadequate to the task of operating such technology under actual conditions of use (Orr, 1986a). Work groups whose members confront technology directly under real operating conditions, on the other hand, are in a position to gain experience regarding its performance and it is these work groups whose members must cope with emergent technological problems in order to do their jobs. Work groups learn the real capabilities and limitations of technology through use, and in response to this reality, they informally create new ways to maximize the technology and/or to cope with its inherent limitations (see for examples Howard & Schneider, 1988; Orr, 1986a; Shimada & MacDuffie, 1986).

The present conceptualization suggests that local knowledge, although at times illicit, actually may support or enhance production and is in fact an integral part of organizational technology. Just as informal organization is an important component of any organizational system and arises "in response to the opportunities created and problems posed by the environment" (Blau & Scott, 1962, p. 6), so local knowledge may be viewed as a crucial component of any technological system—one that also arises in response to opportunities and problems posed by the technological



Source: Adapted from Burawoy (1979), Fry (1982), Kusterer (1978), Vavarek (1988), and Woodward (1965).

Figure 1. Technology—Stucture Relationship
An Interactive Conceptual Model

environment. It seems reasonable, then, to argue that the content and structure of local knowledge systems may be shaped by a sort of technological imperative—a set of implicit technological capabilities and limitations that can only be discovered and overcome as technology operates under actual conditions of use. While such discoveries and solutions are undoubtedly mediated by informal social mechanisms (e.g., troubleshooting sessions among informal work groups; see Sachs, 1988), their fundamental content is a mirror of inherent technological properties. The foregoing argument may be expressed as a formal proposition, stated as follows:

Primary Proposition 1. Technological systems embed an informal component which results from, and reflects, the inherent potential and the limitations of formal technology.

The proposed theoretical position of local knowledge relative to formal technology (and to other dimensions of organizational structure) is depicted graphically in Figure 1. The solid lines and unidirectional arrows in this diagram portray primary determinative (or causal) relationships as they have been characterized in the literature of modern organizational theory.

Technology (in the formal sense) is represented as a primary determinative force in the structuring of both formal (Fry, 1982) and informal organization (Burawoy, 1979; Vavarek, 1987). The diagram also suggests that technology—its potential and its limitations—is a primary motive force driving the creation and content of local knowledge systems.

Mutually supportive and interactive relationships among the technological and structural dimensions of organization are represented in the diagram by broken lines and bi-directional arrows. These interactive relationships include the known influences of formal organization on formal technology and informal organization, documented feedback effects from informal organization to formal structure (Jewell & Reitz, 1981), documented interactions between informal organization and local knowledge (Orr, 1986a), and the probable (but as yet undocumented) relationship between formal organization and local knowledge. The special interaction of formal technology and informal organization which creates bodies of local knowledge (Kusterer, 1978) is represented by a heavy broken line. The need for further research to explore some of the various interrelationships suggested by Figure 1 is considered in the discussion section of this chapter.

LOCAL KNOWLEDGE SYSTEMS IN ADVANCED TECHNOLOGY ORGANIZATIONS

The suggestion of a technological imperative shaping the content of local knowledge leads to the possibility that informal bodies of knowledge may take on a special character in advanced technology organizations. Such organizations are, by definition, dependent on advanced (i.e., high) technology processes and/or products for their competitive positions (see for discussion Balkin & Gomez-Mejia, 1984; examples of advanced technologies discussed later in this chapter include automated inventory planning and control systems, and electronics-based components and end-user products). Advanced technologies, in turn, are complex and rapidly changing phenomena that embody relatively large and expanding domains of formal knowledge. It follows, then, that advanced technology organizations should encompass informal bodies of knowledge that are proportionately more complex and rapidly evolving than those located in traditional organizations. Complex and rapidly evolving systems of local knowledge will be contained specifically (i.e., localized) within advanced technology work sites; that is, bounded work domains associated with advanced technology processes and/or products that are key to an organization's competitive position. This argument may be summarized in a second formal proposition, set forth as follows:

Primary Proposition 2. Local knowledge systems will be relatively more complex and rapidly evolving at advanced technology work sites than at traditional work sites.

This proposition derives from our current understanding of local knowledge as a body of information that responds to and reflects the potential and the limitations of formal technology. Where formal technology is relatively more complex and rapidly changing, the structure and content of local knowledge systems should reflect this complexity and evolutionary change.

It is the rate of technological change that is especially important for understanding local knowledge systems in advanced technology firms. In order to achieve and maintain a competitive position, the key processes and/or products of such firms must coevolve with their technological bases. New developments in process and product technologies within the firms' external (or internal) environment generate corollary technological change within the firm itself—change that brings new problems and limitations (i.e., variances) that must be solved under actual conditions of use. The newness of advanced technologies means that their variances are potentially infinite in nature; that is, the exact character and frequency of variances cannot be predicted in advance. If local knowledge is shaped in some measure by the requirements of formal technology, then we would expect a potentially infinite universe of variances to be reflected by an ever expanding pool of informal coping responses.

The situation described above contrasts sharply with the nature of problems encountered (and solutions enacted) in traditional organizations. In such organizations, technological bases are mature and key process/product technologies are relatively stable over time. In Kusterer's (1978) cone fabricating department, for example, the products being produced were relatively simple (i.e., paper cones for food products) and the production machinery was somewhat antiquated (i.e., 20-years-old). In such traditional technological environments, the number of variances is finite; members of the work group know the various types and frequencies of technological problems that are most likely to occur in the work place. Further, solutions to the vast majority of these problems are known to the majority of the workforce (with the exception of new recruits). The initial establishment of a traditional manufacturing organization may, of course, involve a fair number of unpredicted variances as part of the start-up process. Eventually, however, start-up problems are resolved and the typical variances encountered are those that are known in the industry.

While an individual machine operator might hope to master eventually all (or virtually all) of the regular machine/material variances encountered and solutions enacted at a traditional work site, workers in advanced technology organizations have no such hope. For these latter workers, processes and products are moving targets, constantly changing to keep pace with technological developments. No individual worker can hope to master—via direct experience—all of the ways there are for technology to fail or all of the possible means to cope with technological breakdowns. It is only the total community of workers who together, as a group, experience the total spectrum of technological shortcomings which manifest themselves in the complex and rapidly evolving technological environment. And it is the total community of workers—although perhaps dispersed geographically and/or across long-linked processes—who must devise some means to capture new data gained by individuals and to pool these new data for collective use.

From the foregoing discussion, it is possible to derive three subsidiary propositions (i.e., subsidiary to Primary Proposition 2) concerning the nature of local knowledge systems in advanced technology organizations. Each of these subsidiary propositions (as well as the primary propositions) are supported by empirical evidence drawn from recent ethnographic studies of local knowledge systems at advanced technology work sites (Howard & Schneider, 1988; Orr, 1986a, 1986b, 1988; Sachs 1988). The subsidiary propositions, together with a brief discussion and summary of supporting evidence, are set forth below.

Subsidiary Proposition 1. Individuals and/or informal work groups at advanced technology work sites will create new knowledge in response to technological change, and will contribute such knowledge to an expanding knowledge pool via social mechanisms that enable pooling and sharing of information.

Evidence for the creation and pooling of new informal knowledge has been documented in recent ethnographic studies of technological change. Howard and Schneider (1988) and Sachs (1988) investigated the implementation of automated inventory planning and control systems (Manufacturing Resource Planning—MRP) at an aircraft instruments plant and an electronic components plant, respectively. In both studies, researchers found that MRP (and MRP II) had been designed initially on the basis of an idealized formal representation of reality that did not incorporate informal technical knowledge related to work place production. As a result of this separation of formal and informal knowledge, the automated systems did not work properly in the real-world environment of the plants under study. At the aircraft instrument plant, for example, MRP II would not permit parts to move backward in the production chain, even when components needed to go back to earlier stages for rework (Howard & Schneider, 1988). To cope with such problems, workers developed a new body of informal knowledge that enabled them to

understand MRP requirements and deficiencies, and to manipulate around its rules (thereby reducing costly production bottlenecks and delays). New knowledge about MRP was created and shared during informal shop floor conferences between production workers and inventory control personnel.

A similar process of creating and sharing an expanding pool of knowledge was found by Orr (1986a, 1986b) in his study of Xerox service technicians. The newness and complexity of advanced photocopier models prohibited the development of formal training and documentation that anticipated all of the serious problems that might be encountered by service technicians in the field. New models simply had not been in operation by end-users long enough for designers to know the full range of problems that would emerge over time. Thus, technicians frequently encountered problems that had not been predicted previously or addressed in formal training. Orr (1986a, 1986b) found that when routine repair procedures failed to affect satisfactory results on advanced machines, technicians begin to tell stories about past machine failures. These anecdotes combined information about the machine with the context of a specific situation, allowing technicians to compare the symptoms and diagnostic test results described in narration with new situations encountered in the field. Technicians avidly exchanged narratives (war stories) at every available opportunity (e.g., during breaks at the training sessions), thereby creating a communal memory of problems and solutions. According to Orr, Xerox service representatives share abstract mental models of machines that incorporate formal information gained in training and informal information shared through narratives. When a technician faces an intractable problem in the field, the mental models (partially derived from narratives) suggest tests that should be performed when certain symptoms are encountered. Mental models and communal narratives aid in the organization of new knowledge and serve as a framework for the retrieval of information.

A second subsidiary proposition that may be derived from our general theoretical orientation concerns the structure of local knowledge systems at advanced technology work sites. Due to rapid technological change, local knowledge systems at such sites may be expected to display a distributed (i.e., dispersed or widespread) character over time and space. That is, the content of local knowledge will not be possessed in its entirety by any single individual, but will be dispersed across a work group with each individual possessing varying amounts of information. This possibility exists because rapid change will not permit an individual worker to experience directly all (or the majority) of new technological problems or failures that arise over time. Rather, individual workers or informal work groups will experience and cope with new problems in a decentralized fashion, as problems arise unpredictably over time and space. If local knowledge is distributed at advanced technology work sites, then we also might expect relatively greater variability in the amount of local knowledge possessed by any individual worker. While it is true that individual workers in traditional organizations also possess varying degrees of informal knowledge, it is argued here that such variability in advanced technology organizations is more a function of technological change than of individual aptitude or interest. As a result of this difference, the total system of local knowledge at advanced technology work sites probably cannot be obtained from any single worker (no matter how experienced or talented). This argument is summarized in the following subsidiary proposition, which also derives from Primary Proposition 2:

Subsidiary Proposition 2. Local knowledge systems at advanced technology work sites will display a distributed (i.e., widespread network) structure, with total knowledge content dispersed unevenly among individual workers.

Evidence for the distributed character of local knowledge systems at advanced technology work sites is suggested in results presented by Howard and Schneider (1988), and Orr (1986a, 1986b). In each of these studies, work groups encountered and coped with new technological problems that were distributed widely over time and space. In Howard and Schneider's (1988) research, new problems emerged and new knowledge was created at various points in a linear production process. These points were located at the intersection of normal production problems (typically handled by workers through informal means prior to MRP II) and MRP II system deficiencies (which were caused by an absence of informal knowledge). Although Howard and Schneider (1988) do not address this issue directly, it is presumed that different individuals and/or informal work groups were involved in problem-solving sessions, depending upon the exact time and space location of the intersection points described above. Further, it is suggested (and this is an hypothesis warranting further investigation) that the sharing of new knowledge created at various time-space localities would be affected by the structure of formal and informal organization at the aircraft instruments plant (as indicated in Figure 1).

Orr's (1986a, 1986b) work does address the issue of distributed knowledge more directly, but in his case the distributed character of new knowledge is an obvious function of the geographical deployment of Xerox equipment. Orr's service technicians traveled in small teams, and these teams were the work groups that encountered new technological problems at geographically dispersed field sites. The teams altered their own mental models of machine operation by trial-and-error diagnostic and repair procedures in the field (which, interestingly, drew on distributed sources of information, including end-user reports; see Orr, 1988). New knowledge gained through

dispersed trial-and-error problem-solving procedures was stored in team members' memories and shared through the communal exchange of narratives (which also, presumably, would be a process influenced by formal and informal organizational structure).

A final subsidiary proposition, one that also derives from our general theoretical stance and from Primary Proposition 2, concerns the content of local knowledge at advanced technology work sites.

Subsidiary Proposition 3. Local knowledge systems at advanced technology work sites will include a new type of knowledge content, designated here as knowledge about systems.

Knowledge about systems (a phrase borrowed and adapted from Howard & Schneider (1988), whose meaning was more limited) is defined here as the informal conceptualization of relationships between different parts of large-scale technological processes, including parts that the individual has not experienced directly. This type of knowledge contains informal information about the ways that various parts of a total system do (or do not) fit together. Such knowledge may be used to enable workers to solve, predict, plan for or avoid problems that could occur at other times and/or other places.

Support for the presence of knowledge about systems at advanced technology work sites is presented by Howard and Schneider (1988) and Sachs (1988). In both of these studies, informal work groups developed new bodies of knowledge which were used to *integrate* formal and informal understandings about real production processes on the one hand, and abstract MRP system rules and deficiencies on the other. Sachs (1988) presents an interesting example of knowledge about systems drawn from her study of MRP implementation at an electronics plant. At the plant, inventory control workers discovered a discrepancy between the number of parts of a certain type logged in MRP and the actual number of such parts found in a parts bin. In an effort to diagnose and correct this discrepancy, workers had to compare MRP's record of the parts' movements over time with the logic of actual production steps that were known (by the workers) to involve those same parts. This comparison enabled the workers to pinpoint the source of the discrepancy (i.e., a data entry error) and to reject their initial (and incorrect) hypothesis concerning the origins of the error. Subsequently, the workers were able to locate the missing parts and thereby complete a high priority job. This illustration, plus others presented by Howard and Schneider (1988), shows that informal bodies of knowledge contain information about relationships between different parts of complex technological processes, and that such information may be used to correct problems that originated at other places and times.

DISCUSSION

Kusterer's (1978) work was founded on the belief that workers carry knowledge paradigms as part of their cognitive apparatus, and that such paradigms are altered and expanded through the actual practice of work. While workers at traditional work sites clearly hold and use informal bodies of knowledge that may be described as paradigms (i.e., models or abstract representations of reality), it is the advanced technology worker whose knowledge resembles most closely the dynamic scientific paradigms envisioned by Kuhn (1970). The knowledge constructs of workers at advanced technology work sites are, like scientific paradigms, open systems whose content is constantly altered and expanded through encounters with new problems. And, like scientists, these workers continuously create and share new knowledge that pushes forward the frontiers of their paradigms in step with technological advance. Bodies of local knowledge at traditional work sites, on the other hand, may be more static over time and involve problem-solving practices which rely more generally on known procedures and techniques. It is possible that the dynamic problem-solving process engaged in by workers at advanced technology sites may be fundamentally different from the more static approach taken at traditional sites. Dynamic problem-solving may require more intensive collaboration among informal work groups, or may require substantial opportunities for experimental learning and/or knowledge dissemination among informal networks. It is also possible that differences in the problem-solving process engaged in by workers at traditional and advanced technology work sites may reflect differences in skill levels (although work groups studied by Howard & Schneider [1988] and Sachs [1988] probably were comparable in skill to workers at Kusterer's [1978] traditional site). Each of the possibilities noted above have clear implications for the management of advanced technology firms, and should be investigated through additional empirical research.

Our present understanding of local knowledge systems in advanced technology organizations presents another intriguing possibility, one that also has implications for management and suggests directions for future inquiry. Specifically, it is possible that bodies of local knowledge may be analogous to expert systems. Similarities between these two types of knowledge-based systems becomes clear when we examine the content of each.

An expert's knowledge is founded on a formal domain of data and theory, but also includes content derived from experience with a given class of problems. An especially important component of expert knowledge is the set of explicit and implicit means of evaluating concrete situations and forming plans of attack on complex problems (see Buchanan, 1982). The expert's problem-solving knowledge expands over time as the expert interacts with new types of problems.

Like expert systems, local knowledge systems at advanced technology work sites may be conceived as general problem-solving strategies that emerge from experience with a given class of problems. They also are founded on a formal domain of technical knowledge, include both explicit and implicit means of evaluating and approaching concrete situations, and expand over time in relation to new experience. Significantly, however, local knowledge systems at advanced technology work sites may be more complex than the knowledge carried by an individual expert due to their distributed and collective character; that is, the total content of local knowledge is dispersed over time and space among a group of worker-experts rather than being localized in a single mind. Indeed, it is known that the knowledge carried by individual experts (e.g., physicians, laboratory scientists) also varies across an expert population, and some of these populations have devised social means to pool their expertise (e.g., consultation, delphi techniques) for triangulation on especially difficult or important problems (Barr & Feigenbaum, 1982). What is not known is whether the structure and content of expert knowledge, aggregated over a population of experts, is analogous to the structure and content of local knowledge systems carried by informal work groups at advanced technology work sites. An answer to this question must await further progress in the field of artificial intelligence, as well as additional empirical evidence on systems of local knowledge.

If local knowledge is at least partially analogous to expert knowledge, then it may be possible ultimately to elicit and formally model local knowledge for inclusion in various types of automated systems. The general utility of such formalizations would, of course, depend upon the extent to which local knowledge is specific to a particular technology (versus specific to a particular organization), a question that also remains to be answered in future inquiry. The current problems involved in developing expert systems—including problems involved in using multiple individual experts—suggest that considerable time may pass before it is possible to formalize the collective and distributed expertise of work groups (see Barr & Feigenbaum, 1982). In the meantime, additional research could be undertaken to develop a better understanding of local knowledge systems and optimize their utility in advanced technology organizations.

The diagram presented in Figure 1 suggests a number of possible directions for future research. Several of the relationships depicted in the diagram are not well understood, including the interaction between local knowledge and organizational structure (both formal and informal), as well as the long-term feedback effects from local knowledge to formal technology. One of the most important relationships portrayed in the diagram, and one probably deserving our most immediate attention, is the dynamic interaction of formal technology and informal organization that creates local knowledge over time. This dynamic interaction (indicated by heavy broken lines in Figure 1) is especially significant because of its role in the process of technological innovation. Insofar as local knowledge supports the implementation of new technological processes and products (as suggested by the ethnographic literature), its creation may be viewed as part of the process of technological innovation (see Tornatzky et al, 1982; Tornatzky & Fleischer, 1990). From this standpoint, a better understanding of the knowledge creation process is crucial to the theory and practice of advanced technology management. Some important research questions in the area of local knowledge creation include the following: Exactly how do informal work groups interact with technology to create new knowledge at advanced technology work sites? What are the key variables that affect this process? Is informal collaboration across work groups required in all cases? Do informal leaders or especially gifted workers play a key role? Is new knowledge generation optimized when workers have a better understanding of formal technology? Do quality circles, sociotechnical job design or other types of organizational innovations enhance the creation of new knowledge?

Since technological innovation includes the process of knowledge dissemination, we also need more research on the ways and means by which new informal knowledge is shared among workers. Key research questions in this area include the following: What are the patterns of new knowledge flow and the social mechanisms that support such flow? Does the structure of formal and/or informal organization affect the dissemination of new knowledge across the work group? Do some individuals or informal groups withhold new knowledge from others? What is the rate of new knowledge dissemination and the extent of individual variability in access to new knowledge? Answers to these questions and others given above assume a continuing interest in informal organization, one that could lead us to rethink the position of informal work groups in advanced technology firms. Perhaps such work groups function in a manner that actively supports productivity objectives, more in keeping with the dynamic role envisioned by sociotechnical systems theory (Trist, 1981; Vavarek, 1987) and less like the static and restrictive role portrayed by the neoclassical literature (see Albrecht & Goldman, 1985).

Until the time that local knowledge can be elicited by knowledge acquisition procedures and formally modeled for inclusion in expert systems, managers are advised to map the localities of informal knowledge fields and preserve their integrity in the face of organizational and/or technological change. Because we do not yet have a clear understanding of the exact relationship between local knowledge and organizational structure, any projected change that alters the interface between formal technology and informal organization should be approached with caution.

Ethnographic research suggests that disruption of local knowledge fields (sometimes caused by severing the link between formal technology and informal organization) can cause serious production problems and lead to productivity decline (Howard & Schneider, 1988). Based on our current state of knowledge, work groups that interact with technology in the shop floor or office environment should be viewed as a collective group of experts, experts who must be consulted prior to and throughout the technological change process. Further, informal work groups should be granted adequate time and space to interact with technology in an experimental learning mode prior to full implementation of new technological processes.

Managers may expect to find complex and evolving systems of local knowledge anywhere that work groups interact with rapidly changing material or social technology. Orr (1986a) gives us an excellent means to detect the presence of expanding local knowledge fields; that is, wherever informal work groups share narratives (i.e., war stories) with a technical content. It should be noted, however, that narratives are only one way in which local knowledge can be packaged. Informal technical information also may be created and packaged in shop floor conferences, in the ad hoc training sessions that senior workers give to their juniors, or in organizational myths and ethnohistories. Such informal social phenomena, often portrayed as symbols of organizational culture (e.g., Martin, 1982), also may serve as flags that mark the location of a valuable technological asset. This asset, while virtually invisible on the surface of an organization, is a critical part of the technology-structure interface and should be recognized in future formulations of organizational theory.

NOTES

1. Culture also has been defined as a system of knowledge that is implicit and shared (see Goodenough, 1956). Culture in its traditional sense, however, is an holistic construct that refers to an encyclopedic body of knowledge shared by a social group (Werner & Schoepfle, 1986). In this paper I am using the concept of local knowledge system in a much more focused way (i.e., the informal information shared by a work group which contributes to the operation of a technological system).

2. Kusterer gives many vivid illustrations of machine operators' informal knowledge in each of the four categories listed here. He also presents corroborative evidence from a second case study of informal knowledge acquired by bank tellers (although tellers appear to have a higher ratio of formal to informal knowledge than machine operators). Finally, Kusterer describes more briefly a range of informal techniques and procedures acquired by workers in several different blue and white collar occupations.

3. In Japanese manufacturing organizations, informal knowledge about, and adjustments of machines are a standard feature of the on-going innovation process known as "giving wisdom to the machines" (Shimada & MacDuffie, 1990).

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