CROSSING OCCUPATIONAL BOUNDARIES:
COMMUNICATION AND LEARNING ON A PRODUCTION FLOOR

A DISSERTATION

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Abstract

Using ethnographic techniques of participant observation, my dissertation investigates how skilled workers develop and distribute knowledge on the factory floor of a semiconductor process equipment manufacturer. The engineers, technicians and assemblers involved in the production process have distinct work practices and occupational cultures, yet must share their knowledge in order to produce a viable product. One difficulty in communication between these occupational groups is the different perspective each takes toward the production process. These perspectives, or interpretive schemes, are developed through people's encounters with the technology in their daily work and have consequences for the communication of knowledge and organizational learning.

Communication across occupational boundaries is contingent on the groups' use of boundary objects and language. Technicians mediate the communication process, because they use the boundary objects and speak the languages of both engineering and manufacturing. Most of the misunderstandings in production occur between engineers and assemblers, who do not share a boundary object or language, and I demonstrate how these miscommunications are resolved. I also investigate the social dynamics of learning in this organization, showing how the encoding and use of engineering drawings is a complex social process affected by the occupational groups' interpretive schemes and their relationships with one another.

Finally, I investigate the conditions under which cross-boundary learning occurs in the organization.

This study focuses on several occupations in a high-technology factory setting, thus expanding the tradition of field studies of the social organization of manufacturing work. The theory of organizational communication and learning I develop emerges from detailed observations of the content and social context of learning at work. Based on these observations, I examine not only how learning occurs within occupational communities, but, more importantly, how interactions between members of different occupations affect organization-wide learning. This grounded theory of learning contributes to our understanding of the dynamics of coordination, communication, and knowledge sharing that occur within all organizations.

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While working on a dissertation can be a solitary process for some people, I'm the kind of person who can only get things accomplished after driving everyone around me crazy. In the past couple of years, my family and friends spent countless hours supporting me: offering feedback, providing distractions, and most importantly, listening to me complain. My sister Michelle has always been my staunchest ally; her sense of humor often kept me afloat. My parents frequently reminded me that my room was still available if things got too rough, and I will always remember my sister Stephanie's valiant attempt to cheer me up at my darkest hour.

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CHAPTER 1

INTRODUCTION

In analyzing high-technology manufacturing firms, industry watchers suggest that reducing time to market, improving technology transfer and utilizing concurrent engineering and cross-functional teams will boost a firm to success (Eisenhardt and Tabrizi, 1995). At the root of all these processes is the actual action that takes place in organizations: the work, learning, and knowledge exchange of the organizations' members. The successful manufacture of a product hinges on the interactive efforts of the workers and their communication of knowledge. These workers belong to different occupational groups (i.e. design engineers, technicians) that must work together to produce a viable product. They not only learn the best way to do their own work, but also need to communicate their knowledge to the other groups in the organization.

The integration of functional units, particularly in manufacturing firms, has long been a topic of interest to organizational theorists. Lawrence and Lorsch (1967) demonstrated that differentiation within organizations, or the specialization of tasks, leads to different work styles and mental processes, which results in conflict in organizations. They analyzed the integrating mechanisms of firms facing different environments, including communication, influence patterns, and conflict-resolution practices, and found that integration of units was important for organizational performance. At around the same time, Thompson (1967), drawing on the work of March and Simon (1958), argued that organizational coordination practices were contingent on the type of interdependencies in the organization. As organizations advanced from pooled to sequential to reciprocal interdependencies, more complex coordination mechanisms were added to an organization's repertoire. Firms with pooled interdependence relied primarily on standardization, while those with sequential interdependence also used schedules. The most interdependent organizations, those with reciprocal interdependence, required mutual adjustment in addition to the other two coordination practices.

More recently, research on product development has stressed the importance of cross-functional integration (Wheelwright and Clark, 1992; Clark and Fujimoto, 1991). Wheelwright and Clark (1992) created a framework of development phases and activities in which all the different functional groups should be actively involved. They suggested that a firm's choice of timing, frequency, direction, and medium of communication affected the success of this integration; early, rich, bilateral communication was essential for companies in dynamic product markets.

An analysis of differentiation in organizations that focuses solely on coordination and integration mechanisms, however, is incomplete. An understanding of the effects of differentiation also needs to take into account what information is being coordinated; that is, how differentiation affects what knowledge is being transmitted in the learning processes of organizations. In his treatise on working knowledge, Kusterer points out that the formal division of labor in the workplace "determines a job's learning potential . . . not only by the tasks it assigns, but by the interactions it requires with other workers in other job categories" (1978: 137). While most organizational theorists argue that the coordination of functions in organizations is important, they do not examine how issues of learning and knowledge play out within this division of labor.

The business press spills over with advice for managing the 'new' knowledge worker[1]; publications ranging from the Harvard Business Review (Webber, 1994) to the Futurist (Barner, 1996) indicate that the knowledge worker is in ascendancy as we approach the millennium. Although the rhetoric suggests that harnessing the knowledge of workers is vital, there is little empirical investigation of what knowledge is important for getting work done, and how this knowledge is actually used and transmitted by different groups within organizations. To understand how products are built in customized, high-tech manufacturing organizations, the process of knowledge production and transfer needs to be further examined.

Several different research traditions are related to the study of learning and knowledge production, including investigations of organizational learning and ethnographic studies of work practice. The organizational

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[1] The following articles exemplify the press interest in managing knowledge work: "New responsibilities! new pay?" in Industry Week (Verespej, 1994); "Accounting for knowledge" in HRMagazine (Thornburg, 1994); and "Thriving in chaos" in Working Woman (Peters, 1993).

learning literature has sensitized us to the fact that learning is a fundamental activity of organizations. Research on organizational learning is very diverse, stretching from analyses of production curves (Wright, 1936; Yelle, 1979) to studies of organizational routines (Cohen and Bacdayan, 1994) and models of absorptive capacity (Cohen and Levinthal, 1990). This literature offers some suggestions for a framework for studying the development of knowledge and learning between groups in organizations. Research suggests that organizations can learn through institutionalized experience, adaptation and assumption sharing (Shrivastava, 1983); authors also enumerate processes within organizations that contribute to learning, such as knowledge acquisition, information distribution, information interpretation, and organizational memory (Huber, 1991).

While offering a variety of frameworks, theorists of organizational learning to date have had some difficulty in pinpointing the origin and processes of learning. Organizational learning is said to occur across levels of analysis: individuals can learn, organizations themselves can learn, even a population of organizations can learn (Haunschild, 1995). Because learning occurs at many levels of analysis, authors are often unclear about the level at which their analysis applies. For instance, Huber (1991) refers to organizational "units" in his framework of organizational learning, and shifts from discussions of organizations' learning curves to the search behaviors of managers. When authors provide definitions of organizational learning, often those definitions are characterized by a lack of specificity and clarity.[2] However, even when scholars delimit the definition of learning (e.g. Huber 1991: 89; Fiol and Lyles 1985: 803), two core features of organizational learning remain poorly understood: the content of members' knowledge and the action of individuals who do the learning.

Most analyses of organizational learning are abstracted from the actual practices of organizations, and develop models of processes rather than looking at the content of what is learned. For example, there is a growing body of literature that develops mathematical models of organizational learning (Lounamaa and March, 1987; March and Shapira, 1992; March, 1996). This work is typified by James March's "exploration vs. exploitation" tradeoff (March, 1991), in which March models the organizational impact of various factors: individuals' rapid or slow adaptation to the organizational code of norms, turnover rates, and resource allocations. These models are based on assumptions of knowledge and learning on the part of individuals, but they are not grounded in the actual work of learning. What is the content of March's organizational code of norms, for instance? With mathematical models, content and knowledge do not matter, but in real organizations, the content of learning is important. Grounding theories of organizational learning in the details of what people in organizations learn could help refine

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[2] For instance, consider Levitt and March's (1988) definition of organizational routines as "the forms, rules, procedures, conventions, strategies, and technologies around which organizations are constructed and through which they operate...[and] the structure of beliefs, frameworks, paradigms, codes, cultures, and knowledge that buttress, elaborate, and contradict the formal routines" (Levitt and March, 1988: 320). This definition encompasses a very broad range of

models that only make assumptions about content, and add to our understanding of learning processes in organizations.

Another important feature of learning that needs further examination is the action of people in the organization. Many scholars use the term organizational learning as a metaphor, likening organizations to individuals and drawing parallels between organizational learning processes and the cognitive process of individuals (e.g. Hedberg (1981)). In these frameworks, the organization is the actor and the interaction between the organization and the environment is the impetus for learning. For instance, in Cyert and March's Behavioral View of the Firm (1963), organizations exhibit adaptive behavior: organizations search, they have expectations and make choices. People are implicit in their view of the firm and materialize only as "parts of the organization" (Cyert and March, 1963, p. 122). While treating organizational learning as a metaphor does suggest some interesting mechanisms for learning, these mechanisms only hint at the action of individuals that makes learning happen. The metaphor also leads to an assumption that learning processes are the same for everyone in the organization. Further analysis of the actions of individuals in organizations would clarify how learning happens and perhaps challenge this assumption.

This literature is useful in illustrating the importance of learning in organizations and providing examples of how organizations might be said to

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activities and structures in organizations, rather than distinguishing routines as an organizational learning process.

learn. The concept of organizational learning, however, could be enriched by teasing out the different perspectives and actions and the content of knowledge of the different occupational groups within an organization.

Another approach that could potentially add to the study of knowledge and learning in organizations is suggested by researchers studying work from an ethnographic perspective, particularly those who study technical work and occupations. These studies focus closely on the daily action that takes place in organizations as their members go about their work. For instance, my research on the role of technicians in science laboratories (Barley and Bechky, 1994) describes in detail one type of technical work and demonstrates the importance of technician's work and knowledge in the functioning of a laboratory. Similarly, studies of engineering culture and design (Kunda, 1991; Bucciarelli, 1988) illustrate the daily practice of engineers and lay bare their working concerns. Taken separately, each study encompasses the work of a particular occupation. While none examines the interactions between different occupations, this growing body of literature provides a backdrop for studying the intersection of the work of different technical occupations within a single setting. It suggests that closely examining the daily process and content of the work could offer insight into the generation and transmission of knowledge within organizations.

The technical work literature does not explicitly look at learning in most cases. However, anthropological studies (Orr,1990; Lave and Wenger, 1990) suggest that learning is a social process that occurs within occupational communities. Brown and Duguid's (1991) synthesis of this work describes the process by which learners are enculturated: they "acquire a particular community's subjective viewpoint and learn to speak its language" (Brown and Duguid, 1991: 48). Orr's (1990) photocopier technicians are part of a community that tells stories of past experiences when faced with new problems. Through story telling, community members learn not only from their own experience but from the experience of others. Lave and Wenger's (1990) idea of legitimate peripheral participation is also based on membership in a "community of practice" in which learners participate actively in the community as they become members. These useful insights, generated about learning within single occupational communities, could be broadened by describing the organization-wide learning processes that cross these communities.

This ethnographic literature illustrates that the social context of the work is important in learning in organizations, and it also suggests that there are separate communities of practice within an organization that have different social contexts. Therefore, unlike the homogenous picture of organizational learning presented in the management literature, the idea of communities of practice reflects subcultures that have different domains of substantive knowledge and possibly heterogeneous ways of learning (Orr, 1995; Barley and Van Maanen, 1984). However, neither anthropologists nor organization and management theorists have examined the process of learning in organizations closely enough to find out what these heterogeneous ways are and why they matter. There is little discussion in the literature about the actual process of how individual learning results in organizational learning and no analysis of the interaction between separate communities and how it affects the learning process: the difficulties of sharing knowledge across boundaries and reaching a synthesis.

My dissertation will develop a theory of learning that draws on the strengths of both the ethnographic and management literatures, by focusing closely on the daily practice and knowledge that develops at work, but at the same time addressing how learning diffuses from individuals to the entire organization. By examining how individual knowledge spreads across the different occupational communities in organizations, I hope to link individual learning processes to organizational learning. To do so, I will address the issue of learning by investigating several related questions: What do people in organizations know about their work and how do they develop this knowledge? How does the content of the knowledge of distinct occupations in the production process differ? How do members of organizations communicate their knowledge across social, occupational and organizational boundaries?

By focusing on the individuals who play roles in subsystems and on the content of information that is rooted in the knowledge that people have, I will expand current thinking on organizations' learning processes. Looking at the development and flow of knowledge throughout an organization will ground my analysis of learning in the day to day knowledge and action of individuals. By examining learning in the context of work practices, we can also gain an understanding of the social nature of learning within an organization.

CHAPTER 2

RESEARCH METHODS AND SETTING

Many of the conceptions of organizational learning in the literature fall short because they fail to take into account the work and social culture of the organization. Learning occurs in fleeting moments of action, and researchers who are not present at the time learning occurs risk missing vital information about how it happens. Researchers cannot acquire a thorough understanding of learning through survey methods or interviews because the discovery and generation of contextual knowledge at work may not be recognized by participants as momentous enough to recall at a later time. A theory about learning in organizations that is based on knowledge, behavior and action at work therefore requires a method that generates data through close observation of action within organizations. Thus ethnography, an approach that allows the researcher to "grasp the native's point of view" (Malinowski, 1922), was my choice of method. In ethnography, the researcher enters a culture by becoming a part of the particular social scene of interest, learning what the world is like from the perspective of its insiders.

The research site: EquipCo

In order to develop a theory of learning within a customized, high-tech firm, I spent a year as a participant observer at a semiconductor equipment manufacturing company (which I will call EquipCo). EquipCo's 5000 employees built the large and complex machines that other firms, such as Intel, use to fabricate wafers. Of these 5000 employees, approximately 1800 were directly involved in the production process: 570 design engineers, 90 drafters, 60 manufacturing engineers, 140 engineering and manufacturing technicians, 220 assemblers, and the remainder non-technical administrative support such as planners and schedulers. In the year of the study, EquipCo's revenues surpassed $1 billion, and the firm was named one of the top ten process equipment companies in the semiconductor industry for the seventh year running (VSLI Research, 1996). EquipCo primarily produced wafer etching equipment but also manufactured other semiconductor processing equipment. Many of EquipCo's machines were customized to meet the requirements of a particular wafer fabrication facility.

At EquipCo, engineers designed a prototype machine on a CAD system, and then handed off the drawings to a group of technicians to do a 'build verification.' In a build verification, technicians built a series of engineering prototypes from the ground up, verifying and correcting the documentation as they went along. When the drawings were verified as correct, they were released to the manufacturing area, which had a separate assembly team for new products. The assemblers in this group were brought into the technicians' lab to be trained to build the machine, and when they were comfortable building a machine on their own they moved back into the final assembly clean room area.

EquipCo was an ideal site to study learning processes because in many of the labs and work areas at EquipCo, the technical workers were collaborating to solve problems. Previous work on individual technicians' problem solving strategies (Barley and Bechky, 1994) suggested that examining group problem solving in a manufacturing setting might be a fruitful way to generate theories about the development and exchange of knowledge in technical work. EquipCo faced a quickly changing market, and therefore new prototypes were being built all the time. The different occupational groups involved in the production process needed to effectively communicate their knowledge in order to get these machines out the door.

At the time I began my study, EquipCo was divided into three business units based upon the characteristics of the etching process of the machines. Although the engineering and production areas were organized in this manner, however, the Advanced Manufacturing Engineering (AME) area was consolidated into one group that handled the prototyping of all new products. The Vice Presidents of Manufacturing and AME decided that it would be best if I began my study in the AME technician's lab, since this group had a role in developing every single product the firm produced. This decision stemmed both from the Vice Presidents' concern that the different business units had different subcultures and from the interest that the manager of the technician group had in my project. So I began work as a technician in November of 1995.

My roles as an ethnographer

I spent the first five months of my tenure in the technicians' lab. I was introduced to the group by their manager, an ex-technician who had worked personally with many of the group members. I explained that I was a researcher who would be "hanging out" in the lab, and I would not be reporting back to management or evaluating them in any way. I indicated that whatever they said to me would be confidential, and the technicians seemed open to my presence. Building rapport is not an immediate process, but after several weeks of working in the lab, most of the technicians seemed comfortable with me. Each morning I asked to join a specific individual for the day and gave him or her the opportunity to refuse. In the five months that I worked in the lab, only one of the 27 technicians (a newly hired technician) said that he would rather not have me along as an observer.

I became absorbed in the work, observing a different technician each day and working alongside many of them, building subassemblies and making cables. I quickly found several people who acted as 'key informants' and I worked with those individuals most often, focusing on the projects to which they were assigned. These informants provided me with exhaustive detail about their work and the culture of EquipCo. Most of the technicians also invited me to lunch and to bars and parties after work, and I often attended. I spent the first couple of months trying to learn as much about technical work at EquipCo as I could. I did not have a specific research question in mind, but I knew my main interest was in the role of knowledge, skill, and learning in technical work.

There were many other people circulating around the lab and interacting with the technicians: design and manufacturing engineers, assemblers, schedulers and planners. Therefore, my constant presence in the technicians' lab afforded me access to the two other occupational areas in which I had an interest: final assembly and design engineering. After a few months, two of my key informants began the process of handing off their projects to manufacturing. At this point, several members of the final assembly new products team came into the lab, and I began to focus my research interest. I noticed that the technicians behaved much differently with the assemblers than they did with each other or me. I had noticed a similar issue when engineers had come down into the lab. I became curious about the ways in which the members of each group communicated with each other: how did learning across these groups occur? These product handoffs were fortuitous for me, because I was able to observe many interactions between the three groups.

In order to understand communication and learning between these groups I needed to learn more about the culture and work of each of the communities themselves. So when the two projects were moved completely into manufacturing after the training period, I asked the assemblers if I could come back into the clean room with them. After their manager agreed, I began working with the team of five new products assemblers on these projects. My role as a member of this group never varied, once the assemblers realized that I was relatively capable: I worked building machines every day. Upon moving into the clean room, we had fewer interactions with members of other groups. A clean room environment mandates that workers wear a special clean room suit, known as a 'bunny suit,' along with gloves, boots, and a hood, in order to reduce the dust particles that can land on the machines and cause air leaks. Occasionally a manufacturing engineer, manager, or technician came into the parts staging area (which was adjacent to the clean room and not as particle-free) or called to ask a question, but very few people were willing to put on a bunny suit and enter the building area.

After four months in the clean room, the amount of work available in the final assembly area declined and I again changed my focus. Having seen the transition from prototype to manufacturing, I was also interested in the transition from design to prototype. Through the technicians, I made the acquaintance of a designer in one of the business units, who agreed to let me work with her for a few months. She introduced me to the fifteen members of her group: some engineers, others designers or drafters. In engineering, my role consisted mostly of observation rather than participation, since most of the work was done on the computer, the phone, or in meetings. During my second week in engineering, EquipCo had a 15% reduction in force, and my employment was terminated. Luckily, none of my informants in engineering were laid off. As I was encouraged by both the engineers and management to continue my study, I finished my field work in engineering after several more months.

Data collection and analysis

Participant observation entails collecting data by several different methods. As an observer, I would watch and listen to what was occurring around me as people went about their work. As a participant, I would try to record my own experiences working at the site and how I felt about them. These methods required both quiet attention and an inquisitive nature. While I was working and watching others, I would ask many questions in an attempt to better understand the work. At first, my questions were primarily description questions (Spradley, 1979), focused on clarifying and elaborating the work that people were doing. But as I became more conversant with the culture and language, I began to ask structural and contrast questions, trying to understand how the different symbolic concepts or categories of the culture related to one another.

In addition to the spontaneous, informal interviews that regularly occurred while I was observing the work, I arranged formal interviews with several informants in each occupational group. The use of drawings was obviously an important part of the work of all the occupations in the production process, and I felt that I needed to elucidate this use through more formal means. I brought two sets of assembly drawings with bills of materials to each interview, and had each informant describe how they would use the drawings. The structure of these interviews was slightly different for the designers than for the technicians and assemblers. I asked the designers to describe how they went about creating the drawings from start to finish, and then we discussed what they thought were the most important aspects of the drawing. In contrast, I asked the technicians and assemblers to describe what they would do when they received the drawings. They discussed both the order in which they would examine the drawings and how they would build the parts illustrated by the drawings, as well as explaining what the most important aspects of the drawings were for building purposes.

Throughout my year in the field as a participant observer, I took extensive notes in a small notepad, attending to both the work people were doing and the interactions they were having. Because final assembly took place in a clean room environment, when I worked there I recorded notes using treated 'clean room' pens and paper. Every evening, I would transcribe my notes, expanding them on my computer to include details that I remembered but did not have time to write down. I could not use a tape recorder, camera, or videotape recorder due to confidentiality concerns expressed by management. Use of these recording devices would have been difficult due to the particle contamination issues as well. However, I was able to collect some of the documents that each group used while performing their work, such as engineering drawings, bills of materials, and meeting agendas.

I have amassed thousands of pages of field notes and supporting documents to use in my analysis. The goal of such thorough data collection is to have a solid basis for generating grounded theory through comparison and contrast (Glaser and Strauss, 1967; Strauss and Corbin, 1990). The grounded theory approach is useful for inductive theory building rather than theory testing. It advocates an intensive process of theoretical sampling, comparing and contrasting instances from the data to build theoretical categories which are then exhaustively described, compared, and interrelated to form a theory. I am using my data on work practices and social interactions within and between technician, assembly and design groups to generate new theories about learning and communication at occupational boundaries within organizations.

CHAPTER 3

THE WORK AND KNOWLEDGE OF OCCUPATIONAL COMMUNITIES

In order to analyze how learning in organizations crosses occupational boundaries, it is first necessary to investigate the content of knowledge and processes of learning that occur within occupational communities. While the process of local learning was similar across the occupational groups at EquipCo, the content of their knowledge was quite different.

The formal education of the occupational groups at EquipCo varied. The design engineers typically held a bachelor's or master's degree in a discipline such as chemical, mechanical, electrical or industrial engineering or in computer science. They were assisted by drafters who held two-year associate's degrees and had therefore been trained in design and drafting skills and the use of computer drafting tools. Most technicians held two-year associate's degrees from technical programs in junior colleges in subjects such as electronics, although some of the advanced technicians had received bachelor's degrees from a technical college such as DeVry, and several had not completed any post-secondary education. Assemblers were not required to have any formal education, and were hired based on their previous assembly experience. However, at least half of the assemblers in the new products team that I studied had a high school degree, and one had some additional technical school training. Many of the technicians and one of the members of the final assembly group continued to attend classes at technical schools while they worked.

The occupational communities not only differed in their formal education, but had distinctive stores of contextual knowledge. While engineers, technicians and assemblers were formally trained in the theory of design, mechanics, and electronics in school, they gained considerable contextual knowledge through their hands-on experience of the work itself (Barley and Bechky, 1994). Individuals incorporated elements of their formal training into their contextual knowledge as they related the more abstract understandings they learned in school to the actual practice of the work. Contextual knowledge also embodies what Harper (1987) calls "knowledge in the body," the knowing that comes from tactile and kinesthetic involvement in an activity. Frequently, contextual knowledge includes a tacit element (Polanyi, 1958) that is difficult to articulate and formalize.

All forms of work entail the development of contextual knowledge. Because occupations are responsible for performing different work, they develop knowledge about different activities, processes, tools, and technologies. Therefore, it is the content of this contextual knowledge that distinguishes different occupational groups. Since contextual knowledge is developed through work practices, and the three communities at EquipCo had different work activities, the content of their knowledge necessarily differed. However, because they were all participating in producing the same product, it is relatively easy to compare the differences in contextual knowledge across the communities in relation to the work that each group performed. The five categories of contextual knowledge involved in production work at EquipCo were: knowledge in the body, knowledge of the product, knowledge of tools, knowledge of organizational procedures, and knowledge of the work role of others in the organization.[3]

Knowledge in the body is the contextual knowledge that individuals have about how to do their work. This knowledge comes from an individual's daily involvement in work activities, and as Harper (1987) suggests, it is grounded in the tactile and physical understandings of the work. Knowledge of the product refers to what individuals know about the machine and drawings that they are producing, while knowledge of tools includes knowledge about the machines, tools and aids that people use in performing the work. What people know about the organizational routines, structures, and administrative processes that circumscribe their work is described by knowledge of organizational procedures. Finally, knowledge of the work role of others includes both an understanding of the roles of other occupational communities in the production process as well as knowledge of the skills and expertise held by others in an individual's social network. The

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[3] After generating these categories, I discovered that Kusterer (1978) had developed a similar categorization scheme in his analysis of the know-how of various occupations, from machine operators to bank tellers. Kusterer's five categories of working knowledge include three which map well onto my categories of contextual knowledge: knowledge of materials handled (which I call knowledge of the product), knowledge of machinery used (which I call tools), knowledge of expected work role behaviors of others (which I call work roles).

differences in the content of knowledge of the three occupational groups is summarized in Appendix 1.

The work and knowledge of engineers

The production process at EquipCo progressed in phases, from design through prototyping to manufacturing. In the design phase, a team of engineers designed a new product, working together and using some drawings from previous designs. After designing the layout of a new machine as a group, the members of the engineering team divided up responsibility for completing the bills of materials and assembly and install drawings.

Knowledge in the body. Since their main work practice was designing the product, engineers' knowledge in the body was rooted in the physical and mental activities of design work, including both drawing and designing. It incorporated their formal knowledge of how to create the drawings on the CAD system, such as how to create bills of materials, assembly drawings, and schematics, and how to link those drawings in the system. Another element of the knowledge in the body of engineers was the ability to 'visualize' the machine while they were designing. In the words of one designer: "I tend to spend lots of time staring at the screen, visualizing in my head. I miniaturize myself to walk through the design, so I can see how stuff relates, and make sure the components don't bump into each other, see how wires fit into holes."

Knowledge of the product. Engineers' knowledge of the product included their knowledge of the drawings, which were the main artifacts that engineers produced, and their knowledge of the machine, which was the end result of the design and production process. Engineers were well-versed in all the elements of the drawings: the different types of representations and views, the proper symbols, the formal terminology for the parts, and the part commodity codes. Their contextual knowledge of drawings also included an understanding of how much detail a drawing needed. Engineers knew that a drawing of a subassembly to be built by assemblers in-house required less elaboration than one for a part to be built by an outside contractor, because outside contractors did not build EquipCo parts as regularly or have access to EquipCo designers and technicians.

Engineers' knowledge of the machine was another aspect of their knowledge of the product, and it was closely related to their knowledge of the drawings. Because engineers did not build, their knowledge of the machine was more theoretical and abstract than their knowledge of drawings. They knew where the parts of the machine should go and how they should fit together, as well as how they were supposed to function. But they often did not actually see these parts in practice, nor did they put them together. Therefore, unlike technicians and assemblers, they did not have grounded knowledge about the order of assembly.

Although they did not frequently come into contact with the machine, engineers had a knowledge of the mechanical and physical properties of the parts which technicians and assemblers often lacked. Knowledge about the center of gravity of a machine, for instance, was essential for design work. Similarly, a knowledge of the materials that made up the parts was also important when designing a machine that had parts that interacted with volatile gases and liquids. Engineers knew what types of materials were more likely to compress, how thick the frame had to be in order to maintain its integrity, and how much tolerance was acceptable in machining a groove for an o-ring.

Knowledge of tools. The knowledge of tools possessed by engineers was also generated by their design work. Engineers primarily used computer aided design tools to create their drawings, although frequently paper and pencil were the tools of choice. Engineers had some knowledge about the tools that technicians and assemblers used to build the machines, but they rarely used this knowledge in their daily work. Engineers used one non-drawing tool frequently in doing design work: the manufacturing management database systems. Engineers needed knowledge of these systems in order to determine such information as whether the subassemblies they called out on the drawings were in stock and which free stock parts were most abundant.

Knowledge of organizational procedures. Engineers' knowledge of organizational procedures was focused on facilitating the process of getting their drawings corrected and disseminated to others in the organization. Therefore, it included knowledge of the engineering change order process, such as who needed to sign off on a particular drawing and how to correctly word a note to send to the change notice analyst (the administrative assistant who was authorized to make the changes in the files). Engineers were also responsible for making sure that the correct parts were received in the production areas. This meant that they were well-versed in the procedures involved with ordering parts, inspecting and rejecting parts, and getting parts reworked.

Knowledge of the work roles of others. Last, engineering knowledge of the work roles of others was influenced by the interactions that they had during their daily work. They had general knowledge of the roles and responsibilities of the members of other organizational communities, including the planners and schedulers, the buyers, the technicians and assemblers, and the other engineering groups. Additionally, they had specific knowledge about members of certain other communities; they knew which people were currently working on particular projects and who had a particular type of expertise. This reputational aspect of their knowledge manifested itself in comments such as "Of all the technicians, Bob's redlines are the best," or "Sandy is a great buyer before lunch, but after lunch she's a bit too tipsy to get much work done." Engineers were also knowledgeable about the skills and habits of suppliers outside of the organization, because they needed to interact with those individuals in order to specify the parts they were designing.

The work and knowledge of technicians

After the engineers created the basic structure for the drawings and sent the bills of materials to the planners to start ordering material, they would send the preliminary engineering drawings to the technicians' lab. This started the prototyping, or build verification, phase of the production process, in which the technicians verified and changed the engineering drawings. The technicians started building from scratch using the preliminary engineering drawings and usually using "down rev" parts. These were parts that had been ordered months before the technicians started to build, and the design had changed enough that the parts were incorrect. The technicians reworked the parts to match the new design and built the machine, changing the drawings and the machine itself as they discovered ways to make it easier to manufacture. The goal, according to engineers and technicians, was to create drawings that would be "transparent;" assemblers could use the drawings alone and not have to think about how to build. Technicians corrected the drawings and sent them back to the engineers, who changed them, if they felt the change was warranted, and then released a new drawing.

Knowledge in the body. Because the technicians' work included both building machines from scratch and correcting drawings, their contextual knowledge differed from that of engineers. Technicians' knowledge in the body was primarily the hands-on knowledge of building, rather than a knowledge of design. Technicians were implementers, not designers, and they spent much more time working and thinking about the machines than about the drawings. Technicians relied on their extensive building experience to help them "get a feel" for how to build each new product. Frequently technicians would interpret drawings in reference to this feel for building the machine. For instance, one technician, Mark, was complaining to another about a drawing for a pump controller. He said, "The designer wants us to do things certain ways and they are just not possible," and demonstrated by putting his hand behind the controller. "I mean, look at this, I can't get my hand back on this box to replace that screw, it just won't fit, we're going to have to remove that back panel." Mark's knowledge in the body, the feel for the machine he had developed through years of building experience, came into play when he considered the feasibility of the engineering drawings.

Like engineers, technicians' contextual knowledge in the body contained an element of visualization. However, while engineers visualized the machine in their heads in the course of designing it on a CAD system, technicians visualized how to place different parts while they were looking at the machine. For instance, one technician told me that his photography background helped him to visualize how the different wires could best be routed inside the power distribution box.

Knowledge of the product. Technicians' knowledge of the product resided predominantly in the domain of the machine. Technicians were very knowledgeable about where the parts fit on the machine and the order in which they were best assembled. They knew the part names and designators, although they were not as knowledgeable as engineers about the precise function of the parts. They had the experience and training to know the function of many of the mechanical and electrical components such as thermal couples, resistors, and solenoids, but did not know very much about the etching process and consequently were vague about the function of some of the subassemblies such as the upper match, the focus ring, and the monochrometer.

Technicians' knowledge of the product included an understanding of the requirements that other groups, such as assemblers and service technicians, had for the machine. As they did a build verification, technicians needed to think about issues of manufacturability and servicing and change the machine accordingly. Therefore they had accumulated a store of knowledge about how to make the machine easier and safer to manufacture and service. As one technician pointed out on the AC/DC box he had just finished building: "The designers called out a dozen harnesses, but I identified three separate ones and one smaller one, I tried to eliminate as many of them as possible. Then I routed it so that everything is easily accessible, so you could just pull out the PC board . . . I just optimized access."

Technicians' knowledge of the materials used in building was less extensive than that of engineers, and was much less formal. Engineers were trained in the physical and mechanical properties of materials, while technicians were familiar mostly with those properties that they encountered in the course of building. Therefore, only the few technicians who had extensive soldering experience knew the properties of different types of solder, while almost every technician knew that fiberglass tape was best handled with gloves on unless you were looking for cuts and splinters, because they all had used the tape to wrap the valves on the machine. Similarly, only some of the technicians had been educated in electrical theory, but most knew the basics of signal and voltage from building power supplies or other subassemblies.

Because technicians' work included redlining drawings, they had contextual knowledge of the drawings as well. Their familiarity with the symbols and notations used on all types of drawings allowed them to read drawings with ease. However, unlike engineers, technicians did not really think of the drawings as a product they produced, and their use of their knowledge of drawings was often in reference to building the machine. They would compare the orientation of the drawing to that of the machine, for instance, and make sure that they had all the parts which were called out on the bill of materials.

Knowledge of tools. Technicians used many tools in the course of the building process, from screwdrivers, wrenches, pliers, and crimpers to hoists and leak checkers. Each technician had his own large toolbox and would not use another's tools without asking. Their knowledge of mechanical and electrical tools was far more extensive than their knowledge of drawing tools. Most of the effort technicians put into drawings was in redlining, which entailed making changes with red pen or pencil, and few technicians had any

CAD training. Technicians' knowledge of drawing tools, therefore, was relatively basic and infrequently used. They did, however, have some knowledge of the manufacturing management systems, which they used to figure out where missing parts had been routed.

Knowledge of organizational procedures. Technicians' knowledge of organizational procedures was centered on receiving the right parts and building the machine properly. They were aware of the administrative requirements of the department, and knew the proper procedures for accounting for their work and materials by signing out for kits (although they did not always follow such procedures). They knew how to open work orders for parts, how to fill out non-conformance forms when parts did not meet their standards, and more importantly, who was the proper administrator to sign such forms. Because they were responsible for the quality of the finished machine, the technicians were also knowledgeable about the procedure for handing off a finished product to systems test.

Knowledge of the work roles of others. While technicians were knowledgeable about the general role of other occupational groups in the production process, of all the groups studied, they were the most concerned about their own role in the process. They were very aware that while they could propose changes to the design of the machine, it was the engineer's responsibility to make the final changes. Technicians' knowledge of the role of others also extended to reputational aspects of their social networks, but was more internally focused, as they frequently considered which technician they should ask for help on a particular project and who had completed similar projects before, but rarely mentioned the reputational expertise of other groups' members.

The work and knowledge of assemblers

After several prototypes were built, and the engineers and technicians believed that the drawings were mostly correct, the assemblers were brought into the process. The assemblers trained in the technicians' lab, building the machine as instructed by the technicians. Often they were still receiving down rev parts, and would consult the technicians about how to build the machine properly. Assemblers had access to the technicians' binders of redlined drawings, and sometimes to the latest engineering drawings, and they were constantly told to use only the drawings as a guide to building the machine. However, they rarely used them, as they found it more effective to ask the technicians or other assemblers for help, or to look at a prototype that was already built for guidance.

Knowledge in the body. Assemblers' work was very tactile, and the contextual knowledge in the body that they possessed came from working with the machine and tools. For instance, while assemblers often could not tell the precise measurement of a particular screw, when they saw a hole for it, they could walk to a bin full of different size screws and pick the right one on the first try. Similarly, assemblers knew that building an enclosure was often a trial and error process. Rather than give up after every screw did not fit the first time, they would try putting the screws in several times, manipulating the various parts until they fell into just the right arrangement to allow all the screws to fit.

Knowledge of the product. Assemblers' knowledge of the product was almost completely machine-oriented. Like technicians, they knew how the parts fit together and what was the most efficient order of assembly. They were much less knowledgeable than technicians about the names and functions of the various parts; few assemblers knew the difference between a diode and a resistor, for example. Assemblers contextual knowledge of the materials was almost completely based on their use of the materials in practice. For instance, when cleaning the outside of the machine with alcohol, an assembler demonstrated to me that wiping the alcohol up with a clean rag is less likely to leave a stain around the edge than if he let it air dry. Assemblers were not as familiar with the mechanical and physical properties of the parts as technicians were. However, they were very knowledgeable about the material requirements for a clean room environment, and constantly took issue with technicians' use of unclean materials. Assemblers lacked knowledge of the drawings, because they rarely used them. They only read the drawings with some difficulty, but did cross-check the assembly drawing and the bill of materials when building new subassemblies.

Knowledge of tools. Assemblers' knowledge of tools emerged from their use of tools during the work of building. Assemblers used many of the same types of tools as technicians, but they shared one toolbox rather than keeping individual boxes. The specific tools assemblers knew, such as leak checkers, assembly fixtures, and hoists, differed from those of technicians because assemblers built in a clean room and their method of assembly was more standardized. Assemblers were also knowledgeable about the manufacturing management systems, because they needed to check on their parts to see where they were being staged and what revision was current.

Knowledge of organizational procedures. Most assemblers were not involved in any administrative work, and were therefore not knowledgeable about organizational procedures. The lead assembler in the group was responsible for assigning tasks and communicating with members of other occupational communities, and therefore had some knowledge about procedures such as ordering parts and signing forms for damaged parts and completed machines.

Knowledge of the work roles of others. Assemblers have general knowledge about the work roles of other occupational groups, but like technicians, when they referred to individual reputations, they focused on members of their own community. The assemblers had the most circumscribed sense of their own role. They felt that issues such as the status and progress of the project are the domain of their supervisor or other groups such as engineers and technicians, and were concerned primarily with doing their own work.

Local learning

Within each occupational community, learning occurred locally, centered around the contextual knowledge people developed on the job. People learned from the work that they did and the interactions that they had every day. During the course of the work, people made mistakes and tried to do new things. People learned not only through trial and error when solving mistakes or problems, but they also asked questions and received help from the others around them. For instance, a problem arose when the machine was not leak tight, and technicians gathered around the machine to figure out where it was leaking. The lifter on a chamber wouldn't move upward, and assemblers loosened every screw on the frame to determine why it would not rise. A designer checked some incoming parts, discovered that they were anodized improperly, and called her vendors to fix the problem. In the course of their daily work, as people made mistakes and solved problems, they learned what a machine was supposed to look like and how it should work, and developed ways to build and design it correctly.

As I worked in the technicians' lab, for instance, I learned the value of making mistakes and correcting them (with help from the technicians). Early one morning in my first month of fieldwork I offered to help Martin, a technician, build some subassemblies. I expected that he would show me what to do; instead, he handed me a small rectangular kit box and said, "Go ahead." I got my bearings, reading the pick list to "get a feel for the parts," and opening the bags and laying out the parts on the bench. Martin said to just jump in and figure it out, since that is the "only way to work around here;" when another technician tried to help me, Martin stopped him, saying, "she'll never learn if she doesn't do it herself." The part I was building was an isolation valve, a part of the system of weldments[4] that pulls the air out of the chamber to create a vacuum. I had to wrap the metal valve with insulating rubber, but the drawing was not clear about the correct position of the insulation, nor on how much tape I should use. I asked Martin, and he replied, "it's up to you, and you should remember that you are the expert on this once you've finished it, and you can make changes as you go along." So I wrapped the glass tape thoroughly around the insulation, and then I completed the subassembly by wrapping it with black rubber tape. Martin and Matt, another technician, offered advice when I asked where the tape should be placed, although they said they had not wrapped this particular part before.

As I was finishing up, Matt pulled another kit down from the shelf to build the same part himself. He asked me if there was anything special he should know, and I pointed out that a small fitting was missing from the kit, but that Ted, another technician, had a stash of the ones we needed. I went out for an hour to help Martin fix a test fixture that had broken, and when I returned I found Matt unwrapping the rubber tape from the valve I had built. He told me that I had accidentally put all the tape on inside out, and he tried to make me feel better by saying, "It is good actually, because when I unwrap it

[4] Weldments are assemblies of metal piping and fittings.

I can see how you did it and it will make it easier for me." So we both had the opportunity to learn from my mistake.

As described above, in the process of learning everyone became an "expert" on building a particular part. Others became local experts at a particular aspect of their work, and their reputation spread throughout the group. For instance, Gail was a new technician who came to the lab from the vacuum technology assembly group, where she had worked on building gas boxes, the enclosures containing all the weldments for delivering different gases to the chambers. The other technicians soon discovered that Gail was a "pneumatics expert" based on her previous experience, and came to her for help when building pneumatics. Similarly, another technician was jokingly referred to as "cable boy" for his wiring expertise. There were local experts in the engineering and assembly communities as well. During the layoff a designer who knew one particular product line "inside and out" was fired, and many of the other designers lamented the loss of his expertise. Oscar, an assembler who worked in the vacuum technology group building chambers, was the local expert that the assemblers called on whenever a chamber problem needed to be solved.

While everyone is an expert in particular ways, learning spreads throughout the local communities through joint problem solving and story-telling (Orr, 1990). While some aspects of building are tacit, such as knowing what size screw fits in a hole or how much torque to apply, many aspects of the work can be communicated. However, most local knowledge is context-specific and understood only in relation to the work itself. As Orr (1995) describes, when context is removed from problem-solving information, it becomes useless to the members of the community. For example, problem-solving among assemblers is dependent on the presence of a machine on which to work, and therefore difficult to do over the telephone. Similarly, engineers often refer to drawings during problem-solving sessions.

One consequence of local learning and the development of local experts is the need for individuals to determine the projects on which others in the community are working. In the technicians' lab, for instance, the supervisors held a weekly lab meeting for the leads to list the activities and accomplishments of each technician. Determining "who worked on this type of problem before" was a staple of everyone's problem-solving repertoire.

CHAPTER 4

THE INFLUENCE OF WORK PRACTICES ON OCCUPATIONAL PERSPECTIVES

Occupational boundaries

Because knowledge develops locally, and because each occupational community develops different knowledge about the work, what happens at the boundaries that exist between groups is of paramount importance. In organizations generally, and at EquipCo in particular, the groups and occupations that participate in the production process are divided by occupational boundaries. These boundaries are defined by the work and organizational structure, but are also social in nature and include physical, directional, temporal, and work-related aspects.

The physical element of the boundaries at EquipCo was shaped by the physical location of the different occupations in the plant as well as the nature of the production process, which required a clean room environment for some tasks. The engineers and designers were located three buildings away from the technicians and assemblers, who were located in the same building. This does not imply that the assemblers and technicians were physically close to one another: in addition to a maze of corridors between the two groups, assemblers worked in a clean room environment and any prolonged contact with other groups therefore required "suiting up" on somebody's part. These physical boundaries served as a barrier between occupational communities.

The production process was directional: engineers designed a product and communicated the design through the drawings they generated. Then the product was refined through prototyping in the technicians' lab, and finally the manufacturing version was built in the assembly area. This sequential interdependence also served as a boundary, because the downstream groups had to wait for the upstream groups to do their work before they could get started. For instance, if the engineer had not finished drawing a subassembly, then a technician could not build it. And if the technician had not refined the design or the engineer had yet to make the changes on the drawing, then the assemblers received the wrong parts and had problems building. Temporal boundaries were intertwined with directional ones, as members of the downstream communities spent time waiting for others to finish before they could start their own work. Products were also handled in different ways based upon their release to manufacturing, so the timing of the change in product status contributed to the boundary between occupational groups.

Occupational boundaries were based on the nature of the work as well as the social status associated with occupational roles. The obvious distinction between technician, engineer and assembler was supplemented by finer gradations such as design engineer or manufacturing engineer, engineering technician or new products technician, subassembly or final assembly. These distinctions led to different expectations for each group and had interactional consequences. For instance, engineers did not expect assemblers to have relevant ideas for the design of a fixture. Similarly, while Oscar was considered an expert on chambers among assemblers, when he trained in the technicians' lab he was seen as a "slacker who always wants to do things his own way and then take a cigarette break." This aspect of occupational boundaries was reflected in the ways members of communities treated one another. The technicians encouraged each other to improvise if they could not find the correct parts or figure out the drawing, making such comments as "use the 12 gauge if there is no 14 gauge wire, just crimp it a lot." In contrast, technicians cautioned assemblers not to improvise, exhorting them to "build to the print!" These differences in behavior were a function both of the different types of work the groups did and of the expectations others had of them based on their social status.

In order for the organization to benefit from local learning, knowledge had to spread across these boundaries. Because learning is so context-based, the crucial times for the organization to benefit from local knowledge was when workers themselves crossed these boundaries, interacting with others and enabling local knowledge to spread across the organization. This happened at several times in the production process: when a product was officially transferred to a new area of the organization in a "handoff," "buyoff" or "launch," during design reviews, and when problems with the product emerged. In such transitions, members of several groups interacted, often around the machines. It was at these junctures that opportunities arose for knowledge to be exchanged.

Interpretive schemes: technological frames and thought worlds

When these opportunities arose, what influenced how several local experts behaved and interacted with one another? The literature on differentiation suggests that the perspectives of different groups could have an impact on integration and conflict (Lawrence and Lorsch, 1967). Researchers have generated several theoretical constructs to encompass these different perspectives, or interpretive schemes. Both Bijker's (1987) and Dougherty's (1992) constructs draw on the work of Fleck (1935). Bijker's 'technological frames', shared by the members of the group, embody the "concepts and techniques employed by a community in problem-solving" (1987: 168) and include theories, strategies, tacit knowledge and practices of use. A frame is interactional rather than simply cognitive: it does not exist in one individual's head, but in the interactions between members of a social group, structuring meanings by "providing a grammar for [attributions]" (Bijker, 1987: 172-173). In contrast with a paradigm (Kuhn, 1970), a technological frame includes not only cognitive assumptions and values, but also social factors and material elements such as artifacts (Bijker, 1995). Technological frames come into being within a social milieu, and are communicated in the interactions between members of a social group.

Dougherty (1992) entitles these interpretive schemes 'thought worlds'; they are defined as communities of "persons engaged in a certain domain of activity who have a shared understanding of that activity" (1992: 182). According to Dougherty, the thought worlds of managers in different functional areas influence the perceptions of the group and result in groups that have difficulty sharing ideas and view each other's concerns as unimportant. In contrast with Bijker (1987), who explicitly ties technological frames to a group's interaction with technology, Dougherty's thought worlds are based on functional distinctions.

Both Bijker (1987) and Dougherty (1992) elaborate on themes or elements that distinguish groups across their technological frames or thought worlds. Bijker (1987), examining the social groups involved in the design of Celluloid, suggests that key problems, problem-solving strategies, and practices of use are among the important elements of technological frames. Dougherty (1992), looking at product development in high-technology firms, focuses on the themes of uncertainties, critical aspects of development, and tasks. Describing these themes helps both to distinguish the differences in the social groups as well as illustrate the consequences of such differences.

While elaborating on these themes could be a useful way to generate descriptions of the occupational groups involved in the production process at EquipCo, it presents several problems. The first is a problem of scope. Bijker stresses the broad nature of a technological frame, and claims it is possible for an analyst to describe each frame unambiguously and show how it explains a course of events (1995: 125). In applying the technological frame idea to EquipCo, it was indeed possible to distinctively describe the technological frames of each group. The occupational communities differed along a variety of elements: goals and practices, relationship with the technology, key problems, problem-solving strategies, requirements for problem solutions, contextual knowledge, aesthetic sense, exemplary artifacts, ownership, authority, discretion, training. However, this list of elements could continue ad infinitum, and neither Bijker or Dougherty suggested dimensions on which to bound the set.

The elements distinguishing these communities resembled a rather long description, raising the second issue: how can a researcher generalize from a grounded description of a technological frame or thought world? The concept has analytic power in situ but does not prescribe or facilitate generalization across sites. While the technological frames that Bijker found among groups of scientists and politicians could explain the development of Celluloid, all of those elements did not apply to the occupational groups involved in production at EquipCo. Nor did the particular managerial themes that Dougherty suggested seem relevant to the EquipCo workers that built machines.

One potential solution to the problems of scope and particularity is to focus on the causal mechanisms behind these different interpretations. Both Bijker and Dougherty suggest that these interpretive schemes are a shared understanding about an activity or technology. Neither researcher engages in detailed analysis regarding the generation of that shared understanding; however, Bijker attributes the development of this frame to interactions within the group with respect to the technology (1987: 172). Relationships with technology is a causal mechanism that differentiates between groups as well generalizes across social settings.

Different groups of people have different interpretations of a technology, based on the social contexts in which they encounter it (Pinch and Bijker, 1987; Mulkay, 1979). An individual's perceptions of a technology shape and are shaped by interactions with that technology (Barley, 1986, 1988; Orlikowski, 1992). For instance, in radiology labs, technologists' encounters with the CT scanner shaped their knowledge of the technology, but their knowledge also shaped their future interactions with the machine, in an evolving theoretical and practical dance (Barley 1988).

Similar to the technologists in Barley's study, on the production floor at EquipCo each occupational group encountered the technology (in EquipCo's case, the product) in the course of their daily work. At EquipCo, the interactions that individuals had with the technology were structured by the work that each performed. The interpretive schemes, therefore, were the result of the work practices of each occupational community, which shaped how they encountered the technology and interacted with one another.

Engineers' work practices and interpretive scheme

Engineers' work practices centered on designing the machines, producing drawings for others to use in building. Engineers' daily work was distant from the machine, and their relationship with the technology was an abstract one, that of generating representations of the machine on paper.

Engineers did not build the machine itself, but created a product in their heads and on their computers, translating their ideas into drawings. Because they did not actually build, as did the other two groups, engineers missed learning about the contingencies of the building process first hand. They had to rely on feedback from other sources to learn about the product as it was being built.

Because engineers' work was primarily the abstract work of design, engineers' encounters with and interpretations of the product were filtered through the lens of the drawings on which engineers' spent most of their time. Engineers were frequently surprised to see that the actual machine did not look like the CAD package and the picture in their heads led them to believe that it would. Upon their first encounters with the product in the technicians' lab, engineers exclaimed things like, "It's way more crowded than it looked on my screen!"

This abstract relationship with the machine was reflected in the engineers' sense of aesthetic pride. Engineers had the utmost stake in the way the drawings looked, and were secondarily concerned with the finished machine. Engineers constantly checked and rechecked drawings before releasing them, because of the pride of ownership and responsibility they felt about signing their name on the bottom of the print. Most vital was that the drawing was correct and had no mistakes. Engineers differed in opinion about whether it was important for their handwritten drawings to look nice, but they were unanimous about making sure the changes they drew by hand were clear to interpret. They had a sense that the design should be "clean;" that is, that the product would do what it should in the simplest manner possible. For example, one designer was asked to create two different drawings of the chamber in order to accommodate a gas ring for special orders. She had originally designed only one chamber that could accommodate both, and was frustrated that the project manager was forcing her to take a "nice, simple" design and bill of materials structure and make it more complicated.

Technicians' work practices and interpretive scheme

Technicians' work took place at a bench in a lab and involved challenging hands-on experience with the product, building a machine from the ground up. Technicians were brokers in the sense that they worked at the empirical interface between engineering and manufacturing, translating the requirements of each group for the other (Barley, 1996). Technicians took the engineers' abstract representations and built concrete machines, correcting the drawings to make the machines easier to manufacture. Since they created a machine from scratch, they had more discretion in developing their own order of assembly, and accumulated more extensive product experience than assemblers. Technicians built a product primarily by interpreting drawings and employing their own and other technicians' experiences in building similar products. Technicians' work practices building the machine resulted in daily, concrete interaction with the technology, but they had the additional task of redlining (correcting) the drawings for the engineers to change the design, which provided them with an abstract understanding of the technology as well.

The interpretive scheme with which the technicians' approached the product was therefore a dual one: technicians perceived the machine in both a concrete and abstract way, thinking about both design and manufacturing issues. The technicians' aesthetic sense also embodied their dual relationship with the technology. Technicians knew the machine inside and out, and wanted the machine not only to "look pretty" on the outside, but to "look pretty" on the inside as well. At the same time, technicians also had an aesthetic sense about simple design, although they did not shoulder as much responsibility for it as engineers did. In one instance, for example, a technician complained about a drawing for a test fixture, saying "It's way too complicated, I'm going to ditch at least half the connectors." Technicians' concern about both technical and design issues stemmed from an understanding of the machine that was both hands-on and mediated by drawings.

Assemblers' work practices and interpretive scheme

Assemblers' work was structured and concrete. Assemblers built in a clean room and followed detailed specifications that allowed them little discretion about how to build the final product. They related to the product in a hands-on manner, in small discrete chunks, by building subassemblies and installing them on a frame to create the finished product. Assemblers learned about a product by building it, but often instead of reading drawings, they copied the work of others building the same machine.

While technicians and assemblers shared the concrete understanding of the machine that is rooted in building, their work building the machines was different. Technicians had a more holistic view of the machine than assemblers, due to their broader experience. They worked on many products from start to finish, while assemblers were more likely to work on a single product or parts of products. When the correct parts were not available, for instance, technicians were likely to move to a different product or part or improvise with what they had on hand. In contrast, assemblers did not have the leeway to improvise, since they followed a specified order of assembly, and they did not have other projects on which to work. When parts were unavailable in final assembly, the assemblers were forced to stop working.

Assemblers' interpretive scheme was grounded in their concrete daily encounters with the machine. When assemblers approached their work they saw a machine that was built in a sequential series of subassemblies. Assemblers' aesthetic sense was also based solely on their interaction with the machine. They were proud of the way the machine looked after it had been built, and spent considerable time polishing and cleaning the surfaces of the machine. Unlike technicians, however, who liked the design and the inside of the machine to be neat and orderly, assemblers were primarily concerned with the machine "looking pretty" on the outside. Assembly work focused on the standardized completion of the machine and the concrete interpretive scheme of assemblers reflected this work.

Consequences of interpretive schemes

Interpretive schemes were integral to each group's work and they were most apparent when members of different occupations communicated with one another. These groups interacted frequently during the course of building a new product, as the machines moved from design to prototype to manufacture. Because occupational communities had different perspectives, they perceived the problems with the machine differently and talked about them in a variety of ways. While these different interpretive schemes enabled the members of each occupational community to understand aspects of the machine's functioning that they could not get without the scheme, they also influenced people's interactions, and had consequences for communication and learning in the organization.

Due to their interpretive schemes, for instance, people were often focused on different concerns when faced with production problems, as the following interaction illustrates. Chris, an assembler (**A**), was training in the technicians' lab, building a machine to the documentation. He called over Pat, a technician (**T**), and Alex, an engineer (**E**), to tell them that a label was missing on the enclosure of the generator, so that when field service came out to replace the generator they would not know where each cable should go. They discussed whether or not this label was necessary for field service to replace the generator. Pat argued that in his previous experiences in field service, he would label things himself or just make a mental note before he took things apart. Alex suggested that while the label may not be needed for field service, Chris's point was valid, because they usually label the connectors, and it could be done relatively easily.

Pat (T): The assemblers will have to do it, the manufacturer won't. And the generator will get warm, so the tape won't stick.
Chris (A): On our production line, we make a label.
Alex (E): If you want it in final assembly we can do that.
Pat (T): If it'll give you a warm fuzzy. But you will have to label it at the install level of the generator.
Alex (E): All right, I'll make a change, we can debate it at the ECN (Engineering change notice) meeting, I can already tell you that the engineers are not going to go for it, because its not a form, fit or function problem.
Chris (A): Its a QA (Quality Assurance) problem, we got hit for QA last time because we didn't label it.
Pat (T): The QA guy comes in here a lot, we'll talk to him. You can put it on your install procedure instead of the drawing.
Chris (A): The procedure has to follow the print, if the print doesn't call it out we can't label it.

Alex said he would add a note, and he made a copy of the print and redlined it, saying he would argue with the project manager and twist his arm.

Each person in this discussion had different interests and concerns about how the machine should be built. These concerns were a function of the individual's work practices and reflected their different interpretive schemes. The technician, who had a holistic view of the machine as it would work when completed, was looking ahead to technical issues regarding the functioning of the machine. The engineer was concerned about whether or not the change would be easy to incorporate into the current documentation, because his goal was to complete the documentation quickly. The assembler was worried both about a potential run in with the Quality Assurance people and the constraints that would be placed on his work if the print was not changed.

On another occasion, the different work practices and assumptions underlying the interpretive schemes of engineers and assemblers influenced a conversation about the wording of a drawing. In a meeting about the design of a power feed, John, an engineer (**E**), and Mike, a technician (**T**), were discussing how the note on a drawing should be worded. They called in an assembler who had built the part before, Sue (**A**).

John (**E**): You could use a c-clamp instead of a vise so you should just say 'clamp.'
Mike (**T**): A vise is really preferred, it helps to keep it parallel and even.
Sue (**A**): The vise is better, it works better and leaves access to screws.

After a bit more discussion, they decided to use the term vise. In this example, the engineer knew that there were various tools that might work in this situation, and preferred a broad term that would cover all of the options. The technician, given his experience with the different tools, thought the vise was the best option from a technical point of view, since it would produce the best result. The assembler, on the other hand, who had actually built it using the vise, knew that in this particular situation the vise was helpful not only because it worked better, but because it gave her access to the screws. While Dougherty's (1992) work implies that these differing foci reflect functional interests, the above examples illustrate that the conflict of these interests is rooted in more than functional differences, but emerges from the relationship with the technology in everyday work practice. The source of the conflict is not merely the department in which a person works, but the perceptions of aesthetics, work practices, and relationships with the machine that characterize the interpretive scheme.

The interpretive schemes of the different occupational groups at EquipCo that arise from their distinct encounters with the technology have a variety of implications. In addition to focusing occupational groups on different interests and issues, as described above, interpretive schemes play a large role in whether or not information is communicated between groups and people learn from others in the organization.

CHAPTER 5

THE USE OF LANGUAGE AND BOUNDARY OBJECTS IN COMMUNICATING ACROSS OCCUPATIONAL BOUNDARIES

Interpretive schemes influence communication between members of different occupational communities both through their structuring of the groups' use of technology and their instantiation in language. Because assemblers' work was focused on building, they used the machine as a communication object. In contrast, engineers, whose primary task was to create drawings, used the drawings to communicate, while technicians, who worked with both objects, employed machines and drawings.

The languages of the three occupational communities similarly reflected their interpretive schemes. The assemblers' hands-on, tactile relationship with the machine led them to speak in a language that referred directly to the physical presence of the machine. In contrast, engineers spoke the more abstract, formal language used in the end product of engineering, the documentation. Technicians, who worked closely with both technologies, spoke both languages. These local languages embodied the distinct perspectives each occupation brought to bear on the work of producing a machine.

One difference in terminology that reflected the communities' interpretive schemes was the use of the word 'workmanship.'

'Workmanship' denoted the skill and effort one put into building the product outside of what was directed in the print. For technicians and assemblers it was frequently used positively to reflect their sense of aesthetics and quality. Technicians wanted the workmanship in their lab to be perceived positively by outside groups. However, engineers usually spoke about workmanship when they perceived an absence of quality work by other groups, implying that the person or group who built the product had a low quality standard. For instance, when one engineer was presented with a plate that improperly fit on a frame, he blamed the problem on workmanship, claiming, "it isn't a problem with the documentation, it is a workmanship issue." Even the terms the groups used to talk about the documentation reflected their different schemes. Engineers called the blueprints 'drawings', assemblers called them 'prints', and technicians used both terms. While these different ways of communicating supported the work within each occupational community, they sometimes hindered understanding across groups.

The dynamics of boundary crossing

As described in previous chapters, the occupational communities involved in the production process, while interdependent, were not in close proximity or physical contact with one another. Members of these groups had opportunities to interact across occupational boundaries during formal meetings, training for handoffs, and informal problem-solving sessions.

They also communicated the information needed for production through the use of boundary objects.

Boundary objects are those that "inhabit several intersecting social worlds and satisfy the information requirements of each of them" (Star and Griesemer, 1989: 393). Star and Griesemer (1989) demonstrated how various boundary objects, such as repositories, ideal types, and standardized forms, were used in the organization of the Museum of Vertebrate Zoology at the University of California at the turn of the century. These objects -- diagrams, atlases, specimens, indexes, and even the museum itself -- had different meanings in different social worlds but had a common structure that made them recognizable across these worlds. As a result of their flexible structure, they served as a means of translation between the groups involved in the development of the museum.

At EquipCo, two boundary objects were central to the communication of information and the organization of the production process: the engineering drawings and the prototype machines. The engineering drawings were the legitimate means of communication between the occupational communities: all information needed in production was thought to pass through them.[5] In contrast, while prototypes were used in

[5] The sociology of science literature offers several reasons for the legitimacy and primacy of engineering drawings as communication devices. Both Ferguson (1992) and Latour (1986) point out that drawings allow visual information to be reliably transferred across space and time. Additionally, Latour (1986) suggests that one source of the power of drawings is their creation of a common place for other information to come together (such as tolerances, sales information

practice as boundary objects, they were not perceived as a legitimate way to communicate within the organization.

These objects are embedded in the social and work organization of each occupational community, and are interpreted differently by each group. In this chapter, I will elaborate on their use at the three different occupational boundaries in the production process (between engineers and technicians, technicians and assemblers, and engineers and assemblers), in order to clarify the consequences of the interpretive schemes of the three groups for communication processes in the organization. Appendix 2 illustrates an overview of these boundaries.

Engineers and technicians

Because engineering work focused on the design of a machine, engineers spent much of their time creating and using drawings, and little time working with the machines. Engineering drawings were intended to both show designers how their ideas worked on paper and show assemblers all the information needed for building (also see Ferguson, 1992). They explicated the way to build a machine, from the precise terms calling out each part to detailed notes standardizing the manner in which the parts should be assembled.

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or task information), thereby joining realms of reality (mechanics, economics and the organization of work) that otherwise are difficult to bridge.

Technicians also worked closely with the drawings, using them as a guideline to do the build verification. Although technicians expected that the drawing would be wrong, they used it to explore how to build the part. Technicians changed the drawings, creating redlines, the corrected drawings that illustrated the changes engineers needed to make to the documentation to improve manufacturability.

Because both groups were familiar with the drawings, they served as an effective boundary object: they had a standardized structure that both occupational communities understood, although they were used differently by each group. Appendix 3 shows two versions of the fourth page of an install drawing of a VAT valve: the top one is an engineering version while the bottom is the same drawing with a technician's redlines evident. The design engineer created the initial drawing, which the technician used to build the machine, and then passed the redlines back to the engineer. The technician indicated to me that while all the corrections were not made on the first pass, he repeated his redlines until the changes were finally made. However, the engineer had final authority over any alterations to the drawings.

Because the engineers and technicians shared a schematic understanding of the drawings, they used them effectively as a boundary object, and rarely misunderstood one another in interactions. The way in which the drawings were used and interpreted was embedded in the language spoken within the group (Henderson, 1995). Engineers used drawings as their primary means of communicating, often pulling documents out in the course of conversation. To engineers, the drawing signified precisely what the machine was, and they referred directly to the 'drawing-as-machine' in conversation. For instance, when an engineer said, "the turbo pump," she was far more likely to be referring to an install drawing of the pump than to the pump itself. In this way, engineers' talk echoed the standard language of the drawings.

Because the technicians used the drawings in the course of their work as well, they understood the language spoken by the engineers. It was not uncommon to hear a technician engaging an engineer in a long, abstract discussion about a drawing or machine, as the following discussion in an engineer's cubicle illustrates. The engineer, Greg, and Dan, the technician, were discussing the cable routing for an ACDC box, while looking at a drawing of it on the engineer's computer.

Dan (T):	Would it be better to have a little harness on the power supply? How long is the supply? That would be great for modularity.
Greg (E):	There's the issue of reliability...
Dan (T):	We've done it that way before, although I think space is an issue.
Greg (E):	Space wise I think you might be okay, if you go out in Z direction. This box is almost 11" deep and there's nothing here.
Dan (T):	Could you give me a copy of that top view?
Greg (E):	Sure, and this is the interconnect diagram, you can get kind of the flow... TB1, CB1... (terminal block, circuit breaker).

While looking at the screen together, the engineer and the technician referred casually to the drawing and followed one another's comments with ease. Since creating and interpreting drawings was an important aspect of both groups' work, they shared a common understanding of the boundary object. This does not imply, however, that they shared a complete understanding of one another's work, or even of the engineering drawings. Because technicians spanned the boundary between engineering and manufacturing, they were conversant in both the language of drawings and that of the machine, but they were clearly more comfortable with the hands-on language of the machine. When I asked technicians in the process of building a subassembly "What are you building?," frequently they would answer, "I don't know" and then check that corner of the drawing to find out what it was called. They would, however, know the part's general function and where it would be located on the machine. In contrast, engineers called the parts by the proper names, which they used to label the corner of every drawing. They knew the characteristics of every part and how each part fit into the functioning of the entire machine.

Technicians and assemblers

The boundary between assemblers and technicians was also negotiated with relative ease. While engineers and technicians used their shared knowledge of drawings to communicate across their boundary, assemblers and technicians communicated through their understanding of the machine. Their shared understanding of how the machine was built gave them a common ground to talk about work and any problems that arose.

Assemblers' work entailed building the machine, and assemblers rarely referred to drawings in the course of conversation. For assemblers, the drawing did not represent the machine very clearly or accurately. So while they were told to "Build to the print," they rarely did. Instead, they copied the machines that were already built by others. Since the technicians trained some of the assemblers to build a particular product, they often imparted their own understanding of the building process to the assemblers. Because the technicians and assemblers shared an understanding of how to build the machine, they could use the prototypes as boundary objects in communication.

Assemblers' talk was embedded in the concrete context of building the machine, and depended on the concrete reference point offered by the machine itself. If an assembler referred to the "turbo pump", he was probably about to install it on the machine. While assemblers did have access to the engineering language of the drawings, they did not often use the drawings to build the machine, and therefore did not have occasion to learn the engineering drawings' vocabulary and relations between objects.

Because most of their talk occurred in the presence of the physical objects about which they were talking, they communicated by a system that I will call 'visual accounting,' constantly gesturing and watching one another while they talked. Their vocabulary referred to the physicality and spatial relationships of the machine, and even when interpreting drawings they used locational phrases such as "this valve goes around the other side" and "install the manifold here, next to the pump." Assemblers frequently did not even refer to the machine parts by name. When they were standing right next to the machine, they pointed to the part in question; if they were away from the machine, they gestured and offered a description.

Visual accounting incorporated the use of deictic terms, terms that linked talk with its spatio-temporal and personal context, and served to point out or specify, such as the pronoun "this" (Tanz, 1980; Cicourel, 1990). Because it was less verbal than most languages, visual accounting required an insiders' perspective, a shared understanding of the work and the machine, as the following interaction between two assemblers illustrates.

While two assemblers, Dat and Steve, were building a chamber together, a bolt scratched the side of the lifter for the chamber. Dat pointed it out and said, "Uh, oh, its a big scratch, its all the way down." Steve looked at it and the two of them loosened the bolts on the frame and started to pull on the lifter. Dat swung his arms upward, saying, "Let's see if it works, go up," and pushed the button to move the lifter upward. When it did not move, he asked, "How come?" and Steve, pointing to the bolts on the frame, replied, "Because we tightened these, we need to loosen them."

This exchange contained very few spoken words, and most of the meaning was indicated through gestures and deictic terms. In conversation, assemblers usually took for granted the knowledge and understanding of the other assemblers involved, since most of them had previously built the same machines. For instance, while Jon was routing a pneumatics harness around the frame of the machine, he called over to Steve, "Inside or outside? I forget." Steve glanced over briefly at the harness and answered "Inside," and both continued with their work. Jon was aware that Steve had done the routing for this harness before, and Steve only needed to look for an instant at the part Jon was holding in order to answer the question. Their shared context allows assemblers to understand visual accounting and therefore plays a large role in their communication.

Because technicians had hands-on knowledge of the prototypes as well, they related to the assemblers' understanding of the machine. Technicians shared the spatial and physical relationship that assemblers had with the machine, and due to this shared context, they could understand communication through visual accounting. Therefore, when Jon, an assembler, said he needed a tool "that's long and grabs" while he traced the shape of the tool in the air and pointed to where he was going to use it, the technician, Glen, did not hesitate before replying, "You mean the crowfoot," as he went to find the tool.

Similar to the situation between engineers and technicians, the technicians and assemblers did not have a completely shared understanding of their work or the machine. Among other distinctions, assemblers building experience was grounded in the clean room where they accomplished most of their work. As described in Chapter 3, they therefore had knowledge of the different tools and material requirements for the clean room. Technicians, on the other hand, worked in a lab and did not have to worry about the contingencies of the clean room environment.

Engineers and assemblers

At the boundaries where technicians were located, they worked well as brokers: they understood the boundary objects and languages of both engineers and assemblers. The boundary objects worked effectively most of the time, and since the technicians were located in the middle of the production process, communication was often from a base of shared understanding. However, the build verification process was imperfect, and sometimes products completed the cycle with some flaws. When engineers became aware of these problems with the machine, they turned to the assemblers for answers.

It was at this boundary between engineers and assemblers that many of EquipCo's communication obstacles arose. Engineers and assemblers did not share an understanding of the organization's boundary objects. They did not have a common understanding of drawings because assemblers did not read the drawings that engineers spent most of their time creating. Similarly, they did not have a common understanding of the prototypes because engineers did not see or work on the machines that assemblers spent most of their time building. They also did not have a common language to talk about their work. Therefore, communication between engineers and assemblers required more negotiation than communication at the other boundaries.

Miscommunication between engineers and assemblers

A lack of shared context in using the boundary objects and their different languages posed some communication problems for engineers and assemblers. Miscommunications between the two communities can be characterized as one of two types: homonyms and decontextualizations. A homonym was the use of the same word with different meanings, and a decontextualization was the use of different words to talk about the same object.

Homonyms. One type of miscommunication in interactions between engineers and assemblers resulted from the inadvertent development of homonyms across the languages of the groups. Their languages were based on their different work practices and relationships with the technology, and therefore similar terms with different meanings had developed in their lexicons. This meant that during an interaction, members of different groups used the same signifier but were referring to different objects. Homonyms frequently manifested when assemblers were asked a question and offered a response in the visual accounting lexicon that was the same as a term in the engineering drawing lexicon. The different meanings of the term resulted in confusion.

For example, Gary, an engineer, came to the door of the assemblers' lab one morning after another engineer reported a problem with the frame for the machine. He asked the assembler, Dan, what the problem was. Dan replied, "The holes for the slide don't line up."

Gary asked, "What do you mean, for the slide? There wasn't a problem with the electrode slide. It's the one with the ten holes, only nine of which get screws, right?"

Dan corrected Gary, saying, "No, it has six holes."

Gary disagreed: "No, 10."

Dan then went to the parts area and pulled the frame out of a box to show Gary the holes, and Gary realized that Dan was talking about a different set of holes, not the holes for the electrode slide.

To the engineer, the word "slide" connoted the term 'electric slide' in the lexicon of the engineering drawing language. For the assembler, on the other hand, the "slide" was one of a class of parts in the visual accounting lexicon: parts that physically slide. Sometimes technicians also did not recognize visual accounting terms used by assemblers when they overlapped with those that had a different meaning in the engineering language. This is exemplified by a situation in which an assembler, Steve, demonstrated to a technician how he would cut a long tube. Steve requested, "I also need an angle."

The technician, Glen, replied, "I don't have one of those."

Steve repeated his request to the lead assembler, Dat, who then said, "Oh, he needs another conduit, we have those."

Glen, the technician, thought he did not have the part because he had a different idea of what Steve meant by an "angle." Dat, another assembler, knew the part to which Steve referred, and explained using the term in the engineering lexicon that cleared up the confusion for the technician.

Decontextualizations. While a homonym was the use of the same words with different meanings, decontextualization was the use of different words to talk about the same object. Engineers and assemblers did not share the same context in working with the technology, and therefore they talked about the same object in different ways. Because engineers and assemblers understood the machine differently and focused on different aspects of the building process, even when they were talking about the same machine, they often did not have the perspective that they needed to understand the others comments.

For example, one day in final assembly, an engineer, Chris, came to the parts room in the assemblers' area to ask Steve about some chips on the inside of one of the chambers. Chris inquired, "How did the chips get there?"

Steve, gesturing upward with both hands, responded, "When you lift the plate, a screw gets caught."

Chris did not understand, so Steve said, "I'll show you," and went back into the lab, returning with the upper plate of the chamber cover. He showed the plate to Chris, pointing out the screw on the corner that moved and caused scratches inside the chamber.

The assembler, Steve, had begun by answering Chris's question without being able to refer to the machine, since they were outside of the clean room. The engineer did not understand Steve's response because he did not experience the same work context as the assembler. He did not share the assembler's concrete physical understanding of the machine and knowledge about how the machine was assembled. Therefore, he did not realize the significance of Steve's upward gestures and did not recognize the motion as an action of the machine until the assembler brought the part forward to provide an illustration of how the problem occurred in context.

Resolution of miscommunication

These miscommunications are not always easily resolved, or even recognized. Sometimes, language issues passed unnoticed, as in instances when both parties felt they had understood one another even though they had not. At other times, engineers attributed design problems that were found late in the production process to the fact that those people whose work was most affected had not "stressed it as an issue." The lack of resolution of these issues resulted from the groups' different perspectives on whether a change was important enough to be made. Additionally, status issues resulted in members of higher status groups not fully considering feedback from those with lower status. These problems will be described more fully in Chapter 6.

Despite these problems, frequently at the moment when a misunderstanding occurred, a participant noticed it and tried to resolve it. Miscommunications were resolved in two ways: through translations and tangible definitions. Translations were a verbal way to render one group's language comprehensible to the other, while tangible definitions were physical demonstrations that created a shared understanding of the machine, bypassing the need for verbal codes.

Translation. Translation usually occurred when an engineer who used the drawing language did not understand the visual accounting terms used by a member of another group. If someone who understood both languages was present during the interaction, they translated into the drawing language so that the misunderstanding was resolved. This translation was not word for word, but rather, a translation from one context to another. Most often, technicians performed this translation when mediating the communication between assemblers and engineers. For instance, one afternoon in the technicians' lab an assembler mentioned to a technician that the cable on the "motor" was hard to remove. The technician, who had built the machine before, knew which cable caused the difficulty. When he met the engineer later in a meeting, he translated for the engineer that the "harmonic cable" was causing the problem. However, when technicians were not present, assemblers sometimes translated on their own for engineers. I once heard an assembler report to an engineer that the reason they were assembling the chamber manually rather than using a hoist was that "the hoist proved to be inefficient." I never heard the term 'inefficient' used in the final assembly area before or after that one instance.

Tangible definition. However, tangible definition was far more frequently used to resolve communication problems between assemblers and engineers. Translations required a third party, and, since they were verbal, still left room for misunderstanding and a lack of resolution. A tangible definition, on the other hand, was one that physically exhibited the intended meaning. It defined a problem in a material way: it could be touched and did not depend on verbalization. Most often a tangible definition was provided by illustrating the problem with the actual part in question.

For example, one day in the technicians' lab, an assembler, Harry (**A**), and the lead assembler, Dat (**LA**), were helping an engineer with some details on the design of a fixture to lift the turbo pump. George, the engineer (**E**), said, "The fixture can lift it up about 8 1/2 inches."

Pointing to the legs at the bottom of the pump, which was sitting on the floor next to the machine, Harry (**A**)asked, "Can these four feet be sitting there?"

Dat (**LA**) clarified, "He's talking about the legs of the pump, can those fit on the fixture?"

George (**E**) wanted to know if they could install the legs afterward, but Harry (**A**) indicated not: "They have to come first."

Again, Dat (**LA**) expanded, "The pump comes down with the legs on, will there be clearance?"

After some more discussion, George (**E**) returned to the issue of the legs, asking, "Can we take the standouts off?"

Harry (**A**) said that it would be harder to grab the pump, and George (**E**) replied, "But if you have the jack you don't need to grab it."

"Then how will you get it <u>on</u> the jack?" replied Harry (**A**) quickly.

Dat (**LA**) illustrated, putting his hands around the pump on the floor. "Out here you can lift it up," he said. Moving his hands to the area under the chamber where the pump fit on the machine, he continued, "But in there you can't."

In this example, an understanding of many of the assembler's comments required taken-for-granted knowledge about the process by which the machine was put together. The assembler had a spatio-temporal understanding of the machine: he knew which parts fit where and in what order they needed to be assembled. In contrast, the engineer had a schematic understanding of the machine: he had seen the drawings and had an abstract understanding of how the parts should fit together. The engineer did not have a concrete sense of the order of assembly and he therefore did not understand much of what the assembler said. The lead, however, realized that the engineer needed extra context and translated the assembler's talk into terms familiar to the engineer, by using the term legs rather than feet and clarifying why the clearance was necessary. When the translation proved ineffective, the lead provided a tangible definition, promoting a shared understanding of the machine and resolving the miscommunication.

Frequently, assembler's verbal answers to engineers' questions were not understood, and providing a tangible definition allowed the assembler to bypass verbal communication completely. The tangible definition re-embedded the problem in the context of the machine itself, and, by providing the concrete referent of the actual part, resolved any confusion that a verbal explanation caused.

In many cases, assemblers found tangible definitions for themselves when the drawing was ambiguous. Assemblers felt that other people who had built the product before were more reliable than the drawing. Therefore, when they encountered ambiguity in the drawing, if there was another machine at a more advanced stage of assembly they copied from the machine itself. For instance, watching one assembler route cables I noticed that he checked the drawing frequently but could not find a cable with a matching item number on the machine. He complained that he could not tell where the cables were supposed to go, because on the drawing they disappeared behind the chamber. Then he moved across the room to look at a more complete machine and found the cable, copying its position on his own machine. By following the cables on the more complete machine, the assembler was able to give himself a tangible definition, providing the context that the drawing lacked.

Effective communication practices

Examining effective communication practices also sheds some light on the issues underlying the problems of communicating across groups. Most miscommunications occurred in cases where the communities lacked a shared understanding of a boundary object. Typically, this happened when an engineer approached an assembler with a problem. The assembler did not speak the drawing language but felt pressed to answer, and did so by referring to the machine, usually in deictic terms.

In contrast, when assemblers who practiced visual accounting approached someone that spoke the drawing language, communication was easily accomplished. In these instances, the actions of the assemblers mirrored the two solutions explained above: assemblers generally pre-translated or provided tangible definitions when initially they approached engineers or technicians. For instance, when one assembler, Jon, was having a problem pushing a plastic lock assembly into the proper hole on the door, he decided to ask a technician for help. He carried the assembly with him to the technician's bench and showed it to him, saying, "these things don't fit, you want to try it?" The technician looked at the lock and came over to the machine to help. Bringing the lock over and providing a tangible definition reduced the potential for miscommunication because it gave both participants in the conversation a concrete referent with which to work.

Abstract and concrete communication

The occupational communities negotiated a shared understanding through the use of boundary objects, but they were not always enough. Boundary objects can fail to serve as a translation tool when they are not plastic or flexible enough to be used by all groups. Because these groups had different experiences with the objects and spoke different languages, misunderstandings resulted, particularly between engineers and assemblers.

These misunderstandings were resolved through verbal translation into the language of drawings or by the offer of a tangible definition, which provided the context needed for shared understanding.

The assumption at EquipCo was that the abstract engineering drawings were a better way to communicate in the organization. Abstraction was seen as cleaner and higher-level thinking. However, in practice, concrete communication was often necessary to make sense of the abstract boundary objects. The drawing language was too abstract for assemblers to associate with their concrete understanding of the machine. Also, assemblers mistrusted the drawings, because, in one assembler's words, "with new products there's not enough documentation, or it's wrong... there are always problems." Assemblers often found that that the drawing lacked a concrete referent: the print was ambiguous or wrong and there was no material match for it. The drawing was clear to the designers who created it, because they worked in the context of engineering drawings all the time and had the contextual knowledge needed to understand the drawings. However, assemblers lacked that knowledge and did not understand the drawing without getting added context.

In contrast, the machine was more flexible as a boundary object. Engineers did not understand assemblers' visual accounting language because they lacked the machine-building context and heard assembler's talk through an interpretive scheme that was influenced by their abstract, schematic understanding of the drawings. However, when the machine (or a part) was presented to engineers as a tangible definition, they were able to fit the concrete manifestation into their scheme and negotiate with assemblers to reach an understanding. One technician pointed out the benefits of the concrete when he explained to me why some engineers come to the lab to look at his machine rather than ask questions of other engineers: "Well, things at EquipCo are so complicated, there are so many changes to the product. When you talk in the abstract, there's a good chance that the people you ask will misunderstand and think you are talking about something else, and give you the wrong answer."

CHAPTER 6

LEARNING ACROSS OCCUPATIONAL BOUNDARIES

Because learning across the organization depends upon interaction between members of different occupational communities, it is also influenced by interpretive schemes and the relationships between those communities. The literature on organizational learning often points to the fact that the organization has learned when the local learning of people has been encoded into organizational structures and processes (March and Simon, 1958; Levitt and March, 1988; Huber, 1991). However, researchers rarely investigate the process by which local learning actually gets encoded into routines, artifacts, or standard operating procedures. The codification process within an organization is rarely a smooth one, since the many constituencies involved contribute their own diverging perspectives.

Similarly, theory on organizational learning often assumes that once a routine or an artifact has been encoded, the organization can use that routine in a simple, unproblematic fashion. However, actual organizational practice is far messier than the literature suggests, and these structures and processes frequently require negotiation in daily practice in order to produce a successful outcome.

The construction and use of the engineering drawings at EquipCo provides a good example of how the encoding process actually happens in organizations. The drawings were seen as a repository of knowledge about the building process: they inscribed both what to build and how to build it. However, the creation of drawings was influenced by the social structure of the organization, as members of different occupational communities struggled to provide input. The use of the drawings to build machines was similarly negotiated: assemblers did not simply read and follow the drawing because the knowledge that the drawing encoded was not the most useful knowledge for building. Instead, they relied upon the other resources available to help them build.

In its idealized form, the creation and development of a drawing proceeded as follows: The engineer created a drawing and bill of materials from the layout, starting with the parts that had long lead times so that they could be ordered immediately. She sent the initial drawings to the technicians to build the first prototype. At this stage, as one engineer indicated, "the first cut of the drawings may not be complete, they may not have all the notes. So the technicians call and say they need a torquing spec, or they are going to add flow information on a mass flow controller, or they'll add more detail." Then the engineer incorporated the redlines that the technicians added and sent a new drawing to document control, where it was released to the technicians for the next build verification. After the engineer incorporated the second set of redlines from the technicians, the drawings were released to manufacturing.

The organization was structured with the intent of supporting the effective creation of drawings. The technicians performing the build verifications mediated the relationship between engineers and assemblers, translating feedback from assemblers to provide the information for engineers to incorporate into the drawings. As one technician pointed out to me, "We're the guinea pigs. We correct the things that were wrong with the documentation and give ideas about what would help for when it is manufactured. It is our job to find the problems and make everything flow smoothly." Engineers also acknowledged the importance of the technicians' work in improving the drawings: "We need the technicians as a check and balance, manufacturing isn't set up to do it. . . And the engineers aren't the ones who have to put it together, [problems with the documentation] can be caught in the interim by the technicians who do put it together."

The technicians had a pivotal role in the learning and encoding process, not only because they spanned the occupational boundary between engineers and assemblers, but also because they had access to information across business units and product lines. Since the technicians were the only group at EquipCo that worked on all the product lines, they were uniquely equipped to catch problems that engineers in different business units might duplicate.

The technicians' interpretive scheme and position in the production process also enabled them to cross into both worlds, engineering and assembly. Because technicians understood the languages of both occupational communities, they could communicate with each group as they worked on improving the documentation. Technicians not only participated in the codification process by providing feedback on the drawings to engineers, but participated in the negotiation over the use of drawings while training the assemblers to build.

Feedback between technicians and engineers

Technicians routinely provided feedback to engineers during the build verification process in the form of redlines, or corrected drawings. As they built the machine, technicians would discover problems with the drawings, or learn better ways to produce the product. They would then redline the documentation to reflect what they had learned. For instance, as Dave, a technician, worked on the build verification for an AC/DC box, he noticed that all seven of the ground studs in the box had been designated as points E1 on the schematic. He told me, "They should be labeled E1 through E7, each stud is reserved for something different. The one closest to where the power comes in we designated E1, so an assembler would know that E1 is reserved for grounding the power supply. It is better to do it this way to avoid confusion." After discussing the changes with the engineer, he incorporated them into the drawing, as well as altering the labels on the box itself.

While Dave's ground stud changes were easily accomplished, there were many instances of documentation changes that were not as trouble-free. Occasionally, technicians would be summoned to run down to final assembly with copies of their redlines because the changes they made to the documentation had not been incorporated by engineering or production control. The norm among technicians was to store their binders of redlines from previous build verifications in the event that such problems arose. The communication issues raised in Chapter 5 also affected the implementation of design changes. Technicians sometimes provided ideas that were not incorporated into the documentation, and later, the machine failed because the suggestions had not been given enough urgency. As these examples illustrate, the feedback process between technicians and engineers was influenced by a variety of elements. Factors such as technical problems, timing issues, status differences, the method of feedback, territory conflicts, and knowledge about other groups determined whether the drawing was improved or not.

Technical problems. A technical problem, such as a mistake of fact on a drawing, was the easiest factor to correct in the documentation. For instance, if the engineer called out the wrong size screw, all the technician had to do was replace the part number and the change would be incorporated. Similarly, if a torque specification was missing on the drawing, and the technician added a note, the engineers would incorporate the change without resistance. However, these technical problems could frequently be complicated by the timing of the suggested changes and the perceived status differences between technicians and engineers.

Timing issues. If an engineer's technical mistake was caught by a technician in the early stages of build verification, it was far easier to incorporate a change into the documentation than if the mistake was noticed later in the process. One reason for this was the formal change process that the engineers followed. Certain types of problems were discussed at particular times in the process, and if the technicians offered feedback at the wrong moment, it was not considered to be useful. For example, one day in December, John, a technician, mentioned to Paul, an engineer, that there was an issue in building the emergency off (EMO) assembly. "The problem is, you have to put it together and then at the next step, take it apart again, add a part, and put it back together." Paul replied, "Well, if it is a real issue he can come to us with it, but maybe he should save it for Phase Two, the February 15th meeting, because on my list it says the EMO is all completed." The timing of the suggested change was too late for it to be incorporated into the initial round of drawings, and as a result, the change could not even be considered for two more months.

Status differences. The successful implementation of feedback also depended on whether the interaction raised people's awareness of status differences. If a technician's suggestion was kept private in a one-on-one interaction with an engineer, it was more likely to be easily incorporated into the documentation. Engineer's mistakes that became public knowledge sometimes resulted in hostility and resistance to change. One new technician, Ron, related a story about his first project: "We have to really follow up and make sure that our redlines get incorporated. The engineer on the project, he's the only person I know here because we worked together at my last job. But on my print he called out the wrong size screw in several places, he put 1032 when it was 632. He's mad because I told my supervisor and my supervisor pointed it out in a meeting. The engineer stood up in the meeting and said that we read it wrong, that it was our fault." Even when suggestions did not result in such dramatic blame-laying, engineers sometimes resisted making changes that challenged their authority as designers.

Method of feedback. One way in which technicians could address resistance on the part of engineers was by changing their method of feedback. The more effort technicians made to deliver feedback through standard engineering methods, the more likely they were to have that feedback incorporated. Sometimes technicians would call engineers and suggest changes over the phone, or see them in person to talk about changes. These ideas were not as easily incorporated as those for which the technicians created a engineering drawing to illustrate what they were suggesting. On the main project that Matt was build verifying, for example, he had encountered a lot of trouble in getting his changes incorporated. He mentioned to Lisa, another technician, that the controller she was installing on the pump cart was drawn incorrectly, and she needed to flip it over. "But new documentation from the engineer is on the way," Matt said. Lori asked, "Why would anyone think to flip it over, given how it looks on the print?" Matt replied, laughing, "I know, I told him last night that if he draws it this way it will be built this way, and he said, 'It will?" Lori asked, "Did you see the new drawing, is it any better?" "Well," Matt answered, "it isn't as messy given all the cross-outs you have on your drawing now, but it's probably not really any better. Sorry to bring your morale down." Matt's conversation with the engineer seemingly had little impact on improving the drawing.

In contrast, on another part of the same pump cart, Matt had decided to mount a bracket to a purchased part that was installed on the side. "This is easier than reworking the purchased part to fit, but it will be like pulling teeth to convince the engineers to make the new part. That is why I made a drawing of the part myself." After seeing the drawing, the engineers agreed to add the bracket to the pump cart, and Matt's changes were incorporated into the documentation.

Territory conflicts. Changes that fit within the standard occupational boundaries were more easily incorporated than those in which technicians crossed boundaries. At EquipCo, there was a strong sense of occupational turf: certain tasks were viewed to be in the domain of certain occupational communities. When a change involved crossing into another domain, it was resisted. For example, Larry, a technician, wanted to involve an assembler in the design of the cable harnessing for the AC/DC box of a new product. He approached both the engineer and the manufacturing supervisor on several occasions, asking for assembly input. However, both the engineer and the supervisor refused, citing territorial issues: "Creating a harness drawing is the technicians' job, not the assemblers." Due to their resistance, the harness drawing still had not been created six months later.

Sometimes, because of territory issues, technicians were not even invited to meetings in which they could potentially offer useful feedback. For example, the install and outside reviews included technicians, because these reviews dealt with practical, technical, and cosmetic issues. In contrast, the redesign reviews were considered to be outside of the technicians' domain, and only engineers attended.

Knowledge about others. Finally, the knowledge that technicians had about the needs of other groups served to make the drawing more effective. If the technicians and engineers were aware of the assemblers' needs and the ways in which they would use the drawing, and they incorporated that knowledge into the drawing itself, it made the transition to manufacturing smoother and saved time. For instance, when Joe, a technician, was build verifying a regulator, he used a tappet wrench to attach a valve. He wrote a note on the drawing that said, "Need thin profile 5/8 inch wrench," and told me, "This would be a special tool for the assemblers, its not normally in their toolkit, so I wrote the note on the drawing to let them know that they need to acquire one." Similarly, another technician related a story about the first time he built a test fixture: "I learned a valuable lesson: don't go along with what the engineer or the print says, ask someone who is really familiar with it. When I finished building, I asked Jim (another technician), and he showed me that I put the switches too close together. I did it like the print said, and it works fine, but I should have moved the last switch over an inch, so it would be obvious to the operator which one to flip first. Instead, he'll have to look at the schematic. You really need to think about what the operator would find the easiest."

The feedback between technicians and engineers, therefore, had a great impact on what was encoded in the engineering drawings, the artifacts that represent the organization's learning. As the discussion illustrates, the encoding process is a social one that is influenced by various elements rooted in the relationship between these occupational communities and the knowledge that the groups have.

Feedback between technicians and assemblers

Technicians not only participated in the development of the drawings, but also, as trainers of the assemblers, they contributed to the mediated use of the drawings. According to the technicians, their interaction with assemblers was necessary for various reasons, the most important of which was that there was a lot of information that they could not put into the documentation, or in one technician's words, "you can't put technique into the print." The time spent together in training enables technicians to teach assemblers the information that does not reach the documentation, while also providing a chance to negotiate the building process with the assemblers. As another technician pointed out, "the [assemblers] will build it differently when they leave our lab, so I sit with them to change the document to reflect what they'll do."

When the assemblers come into the technician's lab to train, the technicians' first goal is to teach the assembler how to build the machine. This includes explaining and demonstrating what is written on the drawing as well as adding knowledge that the drawing does not contain. For instance, several technicians participated in the training process one afternoon when Dat, an assembler, worked in the technician's lab. First, Matt stressed to Dat that he use the print to build rather than copy the technician's work, saying as he walked away, "You can put the o-rings on later. And don't be looking at my machine, I'll kill you if I catch you doing that, just look at the print." Shortly after, Matt returned and asked Dat where his gloves were. When Dat indicated that he threw them away because he used Fomblin grease, Matt said, "Where does it say on the print to use Fomblin grease?" Dat checked the print and said, "I guess it doesn't, I thought you always use it" and Matt pointed out the places on the machine it should not be used. Finally, Lisa came over about an hour later while Dat was installing a small block on the side of the chamber. He showed her that it did not stay in place and she said, "Well, you need to use the Lock-tite, since the part doesn't screw in exactly right with the fitting where you want it to be. And you don't want to force it, it might break." He asked how to use it, and she demonstrated as she said, "Just put it on the end of the fitting and screw it on, back it off to the point where the holes line up where you want them. Then you can't move it for 24 hours or it won't seal."

As this example illustrates, throughout their time in the technicians' lab, assemblers were taught to use the drawings as well as given knowledge of many practices that were not available in the drawings. At the same time, as assemblers learned to build, they were providing information for the technicians to incorporate into the documentation. When the technicians thought the assemblers were prepared, the assemblers were given the drawings and a written procedure to try to build a machine on their own. Often, the assemblers would come to the technicians with questions about the drawings or the build process. For instance, Oscar, an assembler, was learning to build the electrostatic chuck and kept coming to Lisa with the documentation to ask questions about the parts. When she went to his bench later to check on his progress, she discovered that he did not attach the fiber optics the way the drawing directed. After demonstrating how he should change them, Lisa said, "Oscar, this is all on the procedure and the prints. If it doesn't make sense, I really need you to tell me, mark it down and ask me what to do next." The information that assemblers provided the technicians about the building process was used to improve the documentation.

Assemblers' use of drawings in practice

After the assemblers left the technicians' lab, they adapted their use of the drawings to the contingencies of their regular work. While they had used the drawings sometimes in the technicians' lab, outside of the presence of the technicians they had developed their own building routine. The drawings were not as useful to the assemblers, because they were too abstract. Assembly work was physical, and the abstract drawings did not speak to the assemblers' concrete interpretive scheme and approach to the work.

The assemblers' building routine was relatively stable: they used prior experience as the basis for their initial action and then verified the work they performed against the drawing. Prior experience manifested itself in three ways: through assemblers' own contextual knowledge, through questioning others, or through copying the work of others.

Contextual knowledge. As described in Chapter 3, assemblers had acquired a vast store of knowledge about how to build as a result of their daily experience. Assemblers drew on this knowledge and applied it to the new situations that they faced. For example, while Dat was reworking some cables, he picked one up and began to change the connector without checking the bill of materials for that part number. I asked him how he knew which type of connector that cable needed and he replied, "I knew it was wrong, a straight connector going into that PC board won't work." He demonstrated to me how the cables would be harnessed on the board, saying, "If you pull them upward in a harness and they are straight connectors, it would bend them right out of the board." Because Dat had built many cables in the past that would connect to PC boards, he knew the proper connector to attach to the cable and had no need to look at the print for the part number.

Questioning others. If they had not built a machine or a similar part before, assemblers drew on the experience of others. During training, this entailed asking a technician what to do, but once the assemblers returned to the clean room, they also asked other assemblers for help. As one assembler explained, "We can build it from the print, but it is easier if we have someone to show us. When you build this, if you are not sure how, you are not confident. Sometimes the print is no good. There are a lot of changes on this project, so the prints are not perfect. When it is different from what you have, you suddenly stop, you are not sure what to do, so it is good to have people around."

Copying others' work. Frequently there would not be anyone around to ask for help, and in these cases assemblers would use physical proxies for others' experience: a previously assembled machine or photographs of a finished product. Assemblers frequently copied the machines that were at a more advanced stage of assembly. For example, when adding some cables to the machine he was building in the technicians' lab, Dat not only checked the technician's machine for placement, but measured his cable against the places where the technician had placed the tie wraps in order to make sure he had the right lengths. Sometimes, assemblers kept photographs of previous machines the group had built, and used those as a reference when building another machine. This was particularly useful for routing pneumatics and cables, because the colors showed up well in the photographs, unlike in the drawings, where everything was in black and white.

Assemblers copied the work of others for the same reasons that they asked for help: "Looking at his (the technician's) work is not only the short way. Yes, it is easier, but it is also better because the percentage of mistakes you make is less, because he's good, man, it's done right. If we do it from the print we can get confused and make mistakes." Although assemblers used the drawings on occasion throughout the building process, they used them primarily as a verification tool: they checked the drawing to see if they remembered correctly, or to verify that the photograph matched the print. The assemblers' routines to extract and employ prior experience in conjunction with their occasional use of the drawings made it possible for them to successfully assemble the product.

Learning in interaction

An important opportunity for learning across occupational boundaries in organizations occurs when problems arise in production, and members of different communities interact to try and solve them. During these interactions, one factor that can affect learning across occupational groups is the interpretive schemes of the people involved.

The different work practices and assumptions underlying the interpretive schemes of engineers, technicians, and assemblers can influence whether they pay attention to one another's input in meetings. For instance, in a meeting about the design of a power feed, John, an engineer (**E**), and Mike, a technician (**T**), were discussing how the note on a drawing should be worded. They called in an assembler who had built the part before, Sue (**A**).

John (E):	We have one person who knows how to build this, that is Sue. Before the SOE (schedule of events) comes in, it wouldn't hurt to add intelligence to the drawing.
Mike (T):	I wasn't sure how to word it so all parties would understand. How would you word it, Sue?
Sue (A):	...Align to connector...
John (E):	We want to put 'input of coil'...but you've built it, Sue, so you already know what we mean. What if you hadn't done it?
Sue (A):	Well, what we do on the floor when we train is have them read the notes and ask us questions about how to do it if they don't understand.
John (E):	So you make up for our poor notes and we appreciate it, but I'd like them to be better.

They decided to have another assembler who had not built the part come in to see if she understood what they meant.

In this example, the engineer thought that what was said on the drawing was important, and therefore he needed to improve it. It was his intention to make the drawing explicit and he also took pride in the quality of his drawings. The assembler, on the other hand, thought that what was more important for assembling the part was watching others do it and asking questions, since this was how work was done in the assembly area. Because the engineer was focused on a different aspect of the process (the drawing's accuracy versus the importance of training), he did not fully appreciate the assembler's explanation of her resolution of the note issue.

One important element of learning in cross-boundary interactions is the ability of the people involved to break out of their scheme momentarily and understand the perspective of others. It is easier for people downstream in the production process to see a part of the perspective of those upstream of them, because that is the normal direction in which information flows. In the production process, information travels from engineers to technicians to assemblers, following the progression and refinement of the documentation. Situations in which information flows in the standard direction are ones in which all parties are comfortable with the sharing of information. Therefore, in training situations, or when upstream individuals have a particular question they want answered, learning across boundaries is more frequent.

Consider the following example, in which two assemblers, Chris and Lee (**A**), being trained in the technicians' lab, were installing a lifter mechanism onto the frame of the machine. They discovered that the lifter would not go up and down because it got stuck on the screws holding the support bracket to the frame. They called over Pat, the technician (**T**), who suggested some ways to fix it. After trying many different fixes like loosening the screws, Pat called down Alex, the engineer. When Alex brought down his drawings and checked the dimensions on many of the parts involved, Pat suggested that the bracket's dimensions might be off. Alex discovered that Pat was right, the bracket is an 1/8" too thick. Alex walked out, saying that they would have to return the bracket and get a replacement.

Lee (**A**):	They don't pay Alex for nothing.
Chris (**A**):	Yeah, I could do that, measuring one or two things, if I had the tools.
Lee (**A**):	Yeah, but why not ask him? It's not your job.
Pat (**T**):	(laughing) yeah, you're an assembler, remember?
Lee (**A**):	They'll ask you, why are you doing that?
Pat (**T**):	Well, at least you guys will know what to look for if it happens again.
Lee (**A**):	If I wanted to do this myself, I'd drill a bigger hole in 1/4" and the screw will go deeper in, that's what I'd do.
Pat (**T**):	You're talking countersink it. But they made the edge of the support bracket too thick.

Lee (A): But if they don't have the parts in stock, they need it now, right away.
Pat (T): It won't work that way though, because this plate being too thick by 1/8" changes everything, all the alignments will be off 1/8".
Lee and Chris (A): Oh, that's right!!!

In this interaction, the assemblers, who were in training and building the machine for the first time, were learning about the machine from the technician, who had broader experience and was able to see the implications of the bracket being too thick. The information flowing downstream helped the assemblers learn about the machine. In the following example (also described in Chapter 5), a manufacturing engineer, Alex (E), came to the lab where the assemblers, Chris and Lee (A), were training, with a specific question in mind. He wanted to get some input about clearance on a fixture he was designing to lift the turbo pump. He brought a drawing with him, and showed it to Chris and Lee while they looked at the machine together. Chris was concerned about the feet of the pump, which were screwed in before it was installed on the machine.

Alex (E): Well, can you install the legs afterward?
Chris (A): No, they have to come first.
Lee (A): The pump comes down with the legs on, will there be clearance?
Chris (A): Is it going to be clean room certified?
Alex (E): I will be happy to take your questions, but I don't know the answer to that one.
Chris (A): Because it needs to be accepted in a clean room.
Alex (E): I'm mostly thinking will we have the clearance, can we take the standouts off?
Chris (A): Then it will be harder to grab it.
Alex (E): But if you have the jack you don't need to grab it.

The engineer left with a better understanding of the clearance problem, knowing what obstacles the assemblers faced when trying to install the pump. This was information he explicitly solicited from the assemblers. However, when the assemblers offered him information about other issues, such as clean room requirements, he returned to the problem that he deemed more important. The assemblers knew that if the fixture was not clean room certified, it would be unusable, since the machine was always built in a clean room. The upstream information about clean rooms was not as relevant in the engineers' scheme, as he never had to install a pump on a machine, and thus he disregarded it. Similarly, assemblers complained that suggestions they offered to engineers for improvements to the machine or to the building process were often ignored. Upstream information often came from lower status individuals whom other groups did not expect to have the knowledge necessary to offer useful suggestions. Individuals upstream attended to information they elicited from downstream groups, but often ignored information that was offered without a request.

These examples illustrate that problems were easier to resolve when they were instigated by higher-status individuals. They also suggest another occasion for learning, an environment in which a problem has arisen. The organizational learning literature suggests that sudden problems or failures lead people in organizations to change their routines and search for new ways of acting (Cyert and March 1963; Argyris and Schon, 1970). At EquipCo, when problems arose, learning across boundaries was more likely to occur, as members of different groups gathered to try to solve the problem.

However, problems do not always result in learning. Tyre, Perlow, Staudenmeyer and Wasson (1996) argue that while learning from problem-solving occurs, given the uncertainty and ambiguity of problem-solving situations, there are many organizational and cognitive constraints on learning through problem-solving. They suggest that another helpful way of looking at adaptation is by looking at "breaks in the action" (1996: 8). Breaks in the action, or interruptions (Gersick, 1989), help focus people's attention, reflect on the work, and work collaboratively.

In boundary-spanning interactions at EquipCo, problems that interrupted the work flow for the groups involved were more likely to result in learning. In the following example, a technician, Pat, called the design engineer, Jane, to let her know there was a problem with a machine leaking, so the machine could not be crossed over to the test lab. Jane discussed the problem with the AME engineer, Alex.

Jane (E):	This morning I got a frantic call from Pat (T), I went down there to the lab. The vat valve is leaking.
Alex (E):	Where?
Jane (E):	In the corner (she shows Alex on the drawing). When they pump down the plate is bowing, the torque isn't spread evenly. 9500 came up with a spacer to deal with the bowing (she showed him the drawing for the spacer).
Alex (E):	To put by the seal ring?
Jane (E):	Yeah, you've gotta go look at the plate. So Pat's (T) pulling the spacers, there are 6 in inventory, that should take up the torque.
Alex (E):	So it torques like this (he curves his hands)?
Jane (E):	It always has done that, but its never leaked before, only bowed.

Alex (E): Why didn't they say so before?
Jane (E): They have mentioned it, but they haven't pushed it as an issue, the machines have always passed. But if it's leaking, now it's time to take care of it.

While the technicians had previously mentioned the problem to the engineers, the problem had never before stopped a machine from moving over to the test area, which would interrupt the production process. As Burns and Stalker point out, "in a manufacturing concern, difficulties anywhere in a system do not usually manifest until they begin to hurt: i.e., until they affect the manufacturing activities" (1961: 163). The moment that the production process is interrupted, the problem is perceived as being critical, and the engineers go down to the lab to work on the problem and learn from the technicians. This suggests a combination of factors: problem-solving and a perceived interruption in the work create a learning opportunity (Tyre and Orlikowski, 1995).

However, it is not merely the fact that an interruption has occurred in production that results in learning. During the previous occurrences of the torque problem, the technicians did not have any tangible evidence that the problem occurred. Since the engineers did not see the plate bowing, and the machines were passing the tests, the problem did not take on definite shape. In contrast, when the machines failed the test, the technicians could provide this evidence in the form of noises during leak check and a form certifying the failure. Similarly, in the other examples described here, tangible evidence of the problem convinced engineers that it required a solution: the scratches on the bracket and the demonstration of the turbo pump. This data suggests that while interruptions and downstream requests are important catalysts of learning, the ability to make a problem concrete could be an even better stimulus.

Learning as encoding through interaction

While encoding provides the organization with a static repository of knowledge, the dynamics of the process of encoding and use of this knowledge are the most important aspect of learning. The relationship between the technicians and engineers influenced what information was encoded, based upon factors such as timing, status, and method of feedback. Similarly, the relationship between technicians and assemblers influenced the way in which the encoded information was used, as the assemblers developed their building routines in part as a response to their training.

The relationships between these occupational groups also shaped the learning processes that occurred during problem solving. Learning was most likely when information flowed down the production stream between occupational communities, for instance. Additionally, the groups' different interpretive schemes determined whether they perceived something as a problem and how they prioritized problems. Finally, a concrete manifestation of a problem at the final stages of production seemed to be the most effective catalyst for learning for members of all occupational groups.

CHAPTER 7

DISCUSSION AND IMPLICATIONS

This dissertation investigated the development of the interpretive schemes of occupational communities and their impact upon organizational communication and learning. By focusing on the work practices of these different occupational communities, I showed that the content of the communities' knowledge and their relationship with the technology influenced the perspectives each group had toward the production process. In turn, these different interpretive schemes had consequences for organizational outcomes: they affected the ways in which the groups communicated, shared knowledge, and learned from one another. Given the effects on a variety of organizational processes, the results of my study speak to several literatures, including work on differentiation and integration, organizational communication, organizational learning, and cross-functional teams.

Differentiation and integration. Looking at the relationship of several occupational groups within a division of labor extends a long tradition within organizational theory of examining the organizational structure of manufacturing firms (Woodward, 1980; Lawrence and Lorsch, 1967; Burns and Stalker, 1961). This research showed that firms organized differently in response to their environments, and the different structures had implications for integration and coordination within the firms. In my dissertation, I found that in addition to its effect on integration and coordination mechanisms, an organization's division of labor also impacts the communication of knowledge and the patterns of organizational learning.

At EquipCo, for example, the technicians' lab was created to differentiate the work of build verification in the hopes that more effective communication during the process would result in a quicker time to market. The technicians' were effective in this boundary spanning role because they were able to translate between the abstract language of the engineers and the concrete language of the assemblers. However, another result of this differentiation was to contribute to the continued separation of conception from execution. The technicians' brokering allowed engineers to continue to work primarily in the abstract, and never get their hands dirty, while assemblers continued to work concretely and never had to understand the abstract drawings. Therefore, engineers and assemblers persisted in having problems communicating and never acquired the knowledge and perspective of the others' work that could potentially enable them to design and build better.

Organizational communication. Describing the effect of occupational communities' interpretive schemes on communication also introduces a new dimension to the organizational communicational literature. Examinations of organizational communication are diverse in their theoretical perspectives, ranging from studies of information processing and media richness (Daft and Lengel, 1984; Trevino, Lengel and Daft, 1987) to supervisory relations (Jablin, 1989) to network analyses of informal communication patterns (Davis, 1953). However, little research has focused on the task and work-oriented communication that workers engage in every day. This occupational communication is an important factor in how work gets accomplished in organizations.

In order to fully investigate the details of daily, work-oriented communication, I adopted an ethnomethodological approach to some portions of my data analysis. Ethnomethodology is the "study of everyday practical reasoning as constitutive of all human activities" (Cicourel, 1974: 99; see also Garfinkel, 1967). An ethnomethodological approach to communication in organizations is one that examines the commonplace practical activity of communicating at work. In analyzing my data, I looked very closely at the daily communicating practices of individuals, with a particular eye toward people's use of language.

It was only through this close examination of language use that I unearthed one of the main findings of my dissertation: concrete communication practices are often necessary to make sense of abstract boundary objects. In other words, while the abstract communication tool, the drawing, was the privileged form of communication in organizations, it was the 'lowest common denominator' in communication, the concrete machine itself, that worked most effectively and quickly to resolve misunderstandings. One implication of this is that organizations that are set up to accommodate concrete communication practices may have fewer communication problems between occupational groups.

Another problem that was created by the organization's focus on abstract forms of communication was a vicious cycle of elaboration that further clouded understanding between communities. Assemblers understood the odds of miscommunication, so tended to be proactive in anticipating and avoiding communication problems by translating and using tangible definitions. In contrast, engineers were less likely to recognize problems of miscommunication, because they had been trained to make the documentation increasingly elaborated in the hopes of 'clarifying' the production process for the assemblers. This drove them to greater abstraction in the documentation, which caused further communication problems. As Hutchins's (1995) study of navigational teams on ships also implies, more of the same type of talk is not necessarily better. Instead of repeatedly elaborating the same form of abstract communication, organization members should change the form of communication (to something more concrete, perhaps) when communicating across occupational boundaries.

There has been little work in the field of organizational communication that focuses on occupational communication practices, and almost none that examines the abstract/concrete dimension (For an exception see Glenn, 1981 for a cross-cultural perspective on abstractive vs. associative communication). One avenue of future research could be an empirical test of the conditions under which concrete communication is more effective than abstract would prove the generalizability of this idea. Additionally, research that further investigates work-oriented communication could add interesting insights to the communication literature as a whole.

Organizational learning. This dissertation also provides a grounded understanding of knowledge development and the process of learning in organizations. Many studies of organizational learning assume that organizations themselves can learn, and they have therefore neglected examining the micro-organizational processes that constitute learning. Those that look at local, daily learning tend to focus on individual learning (Argyris and Schon, 1978; Schon, 1983) as opposed to examining learning as a social process. My theory posits that learning is a social construct rooted in work practices, and that the interpretive schemes of occupational communities influence whether local learning will cross boundaries to become organizational learning.

Looking in a close, grounded way at the process of learning in organizations uncovers the actions that workers take to make organization-wide learning possible. Studying the way the engineering drawings at EquipCo were created and used showed that the process of encoding organizational routines and artifacts was a complex social process. The interpretive schemes of occupational communities influenced the feedback between engineers and technicians: status, organizational protocols, timing, and the method of feedback determined what knowledge was encoded into the documentation. Similarly, these schemes directed the dynamics of the assemblers' use of the documentation in daily practice.

Further, while confirming the importance of several mechanisms for learning such as failures (Cyert and March, 1963) and interruptions (Tyre and Orlikowski, 1995), my research elucidated another important trigger for organizational learning: tangible evidence of a problem. Concrete evidence of a problem enables understanding between different organizational communities, thereby catalyzing the action needed to create cross-boundary learning. Again, the implication for managing is that organizations that support concrete communication and solutions might be more effective.

Interaction of technology and organizational learning. Additionally, much of the research on the social organization of manufacturing has been conducted in mass manufacturing settings (Burawoy, 1979). Even today, the vast majority of attention is being paid to social innovations in high volume assembly plants such as NUMMI and Saturn. While such studies describe the technical and social challenges facing mass manufacturing, they explain little about the requirements of effectively manufacturing complex, customized devices. This dissertation fills a gap in this literature by analyzing the work and social relations of several occupational groups within a customized manufacturing plant. Similarly, it expands the body of literature on technical work to encompass the interaction between three different technical occupations within the same manufacturing setting.

Cross-functional teams. While the literature on cross-functional teams (Clark and Fujimoto, 1992) touches on the relationships between members of different occupations, it does not provide a solution to the problem of cross-functional conflict. The suggestion in this literature is that the functional difference is the source of the problem (Dougherty (1992). Instead, my research illustrates that the root cause of these functional differences lies in the occupation's interpretive scheme, which emerges from their interaction with the technology. The relationship with the technology as the source of the misunderstanding between occupational groups implies that there is a way out of the problem of cross-functional conflict. If it is the relationship with the technology rather than the function itself that causes the problem, then organizations can provide ways for occupational communities to learn to encounter the technology differently.

One way to do this is by enmeshing organization members in the work practices of other occupational groups. This entails more than mere exposure to what other groups are doing, but requires actual encounters with the work product, the type that would be attained through job rotation programs. It remains to be seen whether cross-functional teams actually compel these types of encounters. Therefore, another opportunity for future research would be to investigate the work practices of different occupational groups within cross-functional teams as well as analyze the interpretive schemes that those groups develop.

BIBLIOGRAPHY

Argote, Linda, Beckman, S. and Dennis Epple
1990. "The persistence and transfer of learning in industrial settings." Management Science, 36: 140-154.

Argyris, Chris and Donald Schon
1978. Organizational Learning. Reading, MA: Addison-Wesley.

Barley, Stephen R.
1986. "Technology as an occasion for structuring: evidence from observations of CT scanners and the social order of radiology departments." Administrative Science Quarterly, 31: 78-108.
1988. "The social construction of a machine: Ritual, superstition, magical thinking and other pragmatic responses to running a CT scanner." In M. Lock and D. Gordon (eds.), Biomedicine Examined. Kluwer Academic Publishers.
1996. "Technicians in the Workplace: Ethnographic Evidence for Bringing Work into Organization Studies." Administrative Science Quarterly, 41: 404-441.

Barley, Stephen R. and Beth A. Bechky
1994. "In the backrooms of science: The work of technicians in science labs." Work and Occupations, 21: 85-126.

Barley, Stephen R. and Julian Orr
1996. "The neglected workforce: An introduction." In Stephen Barley and Julian Orr (eds.), Between technology and society: Technical work in the emerging economy. Ithaca, NY: ILR Press.

Barley, Stephen R. and John van Maanen
1984. "Occupational communities: Culture and control in organizations." In Cummings, Larry L. and Barry Staw (eds.), Research in organizational behavior, 6: 287-365. Greenwich, CT: JAI Press.

Barner, Robert
1996. "The new millenium workplace: Seven changes that will challenge managers -- and workers." Futurist, v3n2: 14-18.

Bijker, Wiebe
1987. "The social construction of Bakelite: Toward a theory of invention." In Bijker, Wiebe, Thomas Hughes and Trevor Pinch (eds.), The social construction of technological systems: New directions in the sociology and history of technology. Cambridge, MA: The MIT Press.
1995. Of bicycles, bakelites, and bulbs: Toward a theory of sociotechnical change. Cambridge, MA: The MIT Press.

Brown, John Seely and P. Duguid
1991. "Organizational learning and communities of practice." Organization Science 2: 40-57.

Bucciarelli, Lawrence
1988. "An ethnographic perspective on engineering design." Design Studies, 9, 159-168.

Burawoy, Michael
1979. Manufacturing consent: Changes in the labor process under monopoly capitalism. Chicago, IL: The University of Chicago Press.

Burns, Tom and G.M. Stalker
1961. The Management of Innovation. London: Tavistock Publications Ltd.

Cicourel, Aaron V.
1974. Cognitive sociology: Language and meaning in social interaction. New York: The Free Press.
1990. "The integration of distributed knowledge in collaborative medical diagnosis." In Galegher, Jolene, Robert E. Kraut, and Carmen Egido (eds.), Intellectual teamwork: Social and technological foundations of cooperative work. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Clark, Kim B. and Takahiro Fujimoto
1991. Product development performance. Boston: Harvard Business School Press.

Cohen, Michael and Paul Bacdayan
1994. "Organizational routines are stored as procedural memory: Evidence from a laboratory study." Organization Science, 5: 554-568.

Cohen, Wesley and Daniel Levinthal
1990. "Absorptive capacity: A new perspective on learning and innovation." Administrative Science Quarterly 35: 128-152.

Cyert, Richard and James G. March
1963. A behavioral theory of the firm. Oxford: Blackwell.

Daft, Richard L. and R.H. Lengel
1984. "Information richness: A new approach to managerial behavior and organizational design." In Cummings, Larry L. and Barry M. Staw (eds.), Research in Organizational Behavior, 6: 191-233. Greenwich, CT: JAI Press.

Davis, K.
1953. "A method of studying communication patterns in organizations." Personnel Psychology, 6: 301-312.

Dodgson, Mark
1993. "Organizational learning: A review of some literatures." Organization Studies, 14: 375-394.

Dougherty, Deborah
1992. "Interpretive barriers to successful product innovation in large firms." Organization Science, 3: 179-202.

Eisenhardt, Kathleen M. and Behnam Tabrizi
1995. "Accelerating adaptive processes: Product innovation in the global computer industry." Administrative Science Quarterly 40: 84-110.

Ferguson, Eugene S.
1992. Engineering and the mind's eye. Cambridge, MA: The MIT Press.

Fiol, C. Marlene and M. Lyles
1985. "Organizational learning." Academy of Management Review, 10: 803-813.

Fleck, L.
1935. The genesis and development of a scientific fact. Chicago: the University of Chicago Press. (English translation, 1979)

Garfinkel, Harold
1967. Studies in Ethnomethodology. New York: Prentice Hall.

Gersick, Connie
1988. "Time and transition in work teams: toward a new model of group development." Academy of Management Journal, 31: 9-41.

Glaser, Barney G. and Anselm Strauss
1967. The discovery of grounded theory: Strategies for qualitative research. New York, NY: Aldine de Gruyter.

Glenn, Edmund
1981. Man and Mankind. Norwood, NJ: Ablex.

Harper, Douglas
1987. Working Knowledge: Skill and Community in a Small Shop. Chicago: University of Chicago Press.

Haunschild, Pamela
1995. "Population level learning." In Staw, B. M. and L. L. Cummings (eds.), Research in Organizational Behavior, 17. Greenwich, CT: JAI Press.

Hedberg, Bo
1981. "How organizations learn and unlearn." In P. Nystrom and William Starbuck (eds.), Handbook of Organizational Design, 1: 3-27. Oxford: Oxford University Press.

Henderson, Kathryn
1995 "The political career of a prototype: The importance of the visual in design engineering consensus and conflict." Social Problems, 42: 274-299.

Huber, George P.
1991. "Organizational learning: the contributing processes and the literatures." Organization Science, 2: 88-115.

Hutchins, Edwin
1995. Cognition in the wild. Cambridge, MA: MIT Press.

Jablin, Fredric
1979. "Superior-subordinate communication: The state of the art." Psychological Bulletin, 86: 1201-1222.

Knorr-Cetina, Karin
1981. The manufacture of knowledge: An essay on the constructivist and contextual nature of science. Oxford: Pergamon.

Kuhn, Thomas
1970. The structure of scientific revolutions, second edition. Chicago: Chicago University Press.

Kunda, Gideon
1991. Engineering culture: Control and commitment in a high-tech corporation. Philadelphia: Temple University Press.

Kusterer, Ken
1978. Know-how on the job: The important working knowledge of "unskilled" workers. Boulder, CO: Westview Press.

Latour, Bruno
1986. "Visualization and cognition: Thinking with eyes and hands." Knowledge and Society, 6: 1-40.

Latour, Bruno and Steve Woolgar
1979. Laboratory Life: The social construction of scientific facts. London and Beverly Hills: Sage.

Lawrence, Paul R. and Jay W. Lorsch
1967. Organization and Environment: Managing Differentiation and Integration. Boston: Graduate School of Business Administration, Harvard University.

Lave, Jean and Etienne Wenger
1990. Situated learning: Legitimate peripheral participation. Cambridge: Cambridge University Press.

Levinthal, Daniel and James G. March
1981. "A model of adaptive organizational search." Journal of Economic Behavior and Organization, 2: 307-333.

Levitt, Barbara and James G. March
1988. "Organizational learning." Annual Review of Sociology, 14: 319-40.

Lounamaa, P. and James G. March
1987. "Adaptive coordination of a learning team." Management Science, 33: 107-123.

Malinowski, Bronislaw
1922. Argonauts of the Western Pacific. London: Routledge.

March, James G.
1991. "Exploration and exploitation in organizational learning." Organization Science 2: 71-87.
1996. "Learning to Be Risk Averse." Psychological Review, 103: 309-319.

March, James G. and Zur Shapira
1992. "Variable Risk Preferences and the Focus of Attention." Psychological Review, 99: 172-183.

March, James G. and Herbert A. Simon
1958. Organizations. New York: John Wiley and Sons.

Mulkay, Michael
1979. Science and the sociology of knowledge. London: Allen and Unwin.

Orlikowski, Wanda
1992. "The duality of technology: Rethinking the concept of technology in organizations." Organization Science 3: 398-427.

Orr, Julian
1990. "Sharing knowledge, celebrating identity: War stories and community memory in a service culture." In D. Middleton and D. Edwards (eds.), Collective remembering: Memory in society. Beverly Hills, CA: Sage Publications.
1995. "Ethnography and organizational learning: In pursuit of learning at work." In S. Bagnara, C. Zucchermaglio, and S. Stucky (eds.), Organizational learning and technological change. New York: Springer-Verlag.
1996. Talking about machines: An ethnography of a modern job. Ithaca, NY: Cornell University Press.

Peters, Tom
1993. "Thriving in chaos." Working woman, 18(9): 42-45.

Pinch, Trevor and Wiebe Bijker
1987. "The social construction of facts and artifacts: or how the sociology fo science and the sociology of technology might benefit each other." In Bijker, Wiebe, Thomas Hughes and Trevor Pinch (eds.), The social construction of technological systems: New directions in the sociology and history of technology. Cambridge, MA: MIT Press.

Polanyi, Michael
1958. Personal Knowledge: Toward a Post-Critical Philosophy. Chicago: University of Chicago Press.

Schon, Donald
1983. The reflective practitioner: How professionals think in action. New York, NY: Basic Books.

Shrivastava, Paul
1983. "A typology of organzational learning systems." Journal of Management Studies, 20: 1-28.

Spradley, James P.
1979. The ethnographic interview. Fort Worth, TX: Holt, Rinehart and Winston, Inc.

Star, Susan Leigh and Griesemer, James R.
1989. "Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." Social Studies of Science, 19: 387-420.

Strauss, Anselm K. and Juliet Corbin
1990. Basics of qualitative research: Grounded theory procedures and techniques. Newbury Park, CA: Sage Publications.

Tanz, Christine
1980. Studies in the acquisition of deictic terms. Cambridge: Cambridge University Press.

Thompson, James D.
1967. Organizations in action: Social scientific bases of administrative theory. New York: McGraw Hill.

Thornburg, Linda
1994. "Accounting for knowledge." HRMagazine, 39(10): 50-56.

Trevino, L.K., R. H. Lengel, and Richard L. Daft
1987. "Media symbolism, media richness, and media choice in organizations: A symbolic interactionist perspective." Communications Research, 14: 553-574.

Tyre, Marcie, Leslie Perlow, Nancy Staudenmeyer and Christine Wasson
1996. "Time as a trigger for organzational change." Working paper presented at the annual meeting of the Academy of Mangement, Cincinnati, OH.

Verespej, Michael A.
1994. "New responsibilities? New pay!" Industry Week, Aug. 15, 1994, 243(15): 11-22.

VSLI Research Inc.
1996. Ten Best Process Equipment Companies in 1995. San Jose, CA: VSLI.

Webber, Alan M.
1994. "Surviving in the new economy." Harvard Business Review, 72(5): 76-92.

Wheelwright, Steven C. and Kim B. Clark
1992. Revolutionalizing new product development: Quantum leaps in speed, efficiency and quality. New York: The Free Press.

Woodward, Joan
1980. Industrial Organization: Theory and Practice. Second edition. New York: Oxford University Press. (First edition 1965).

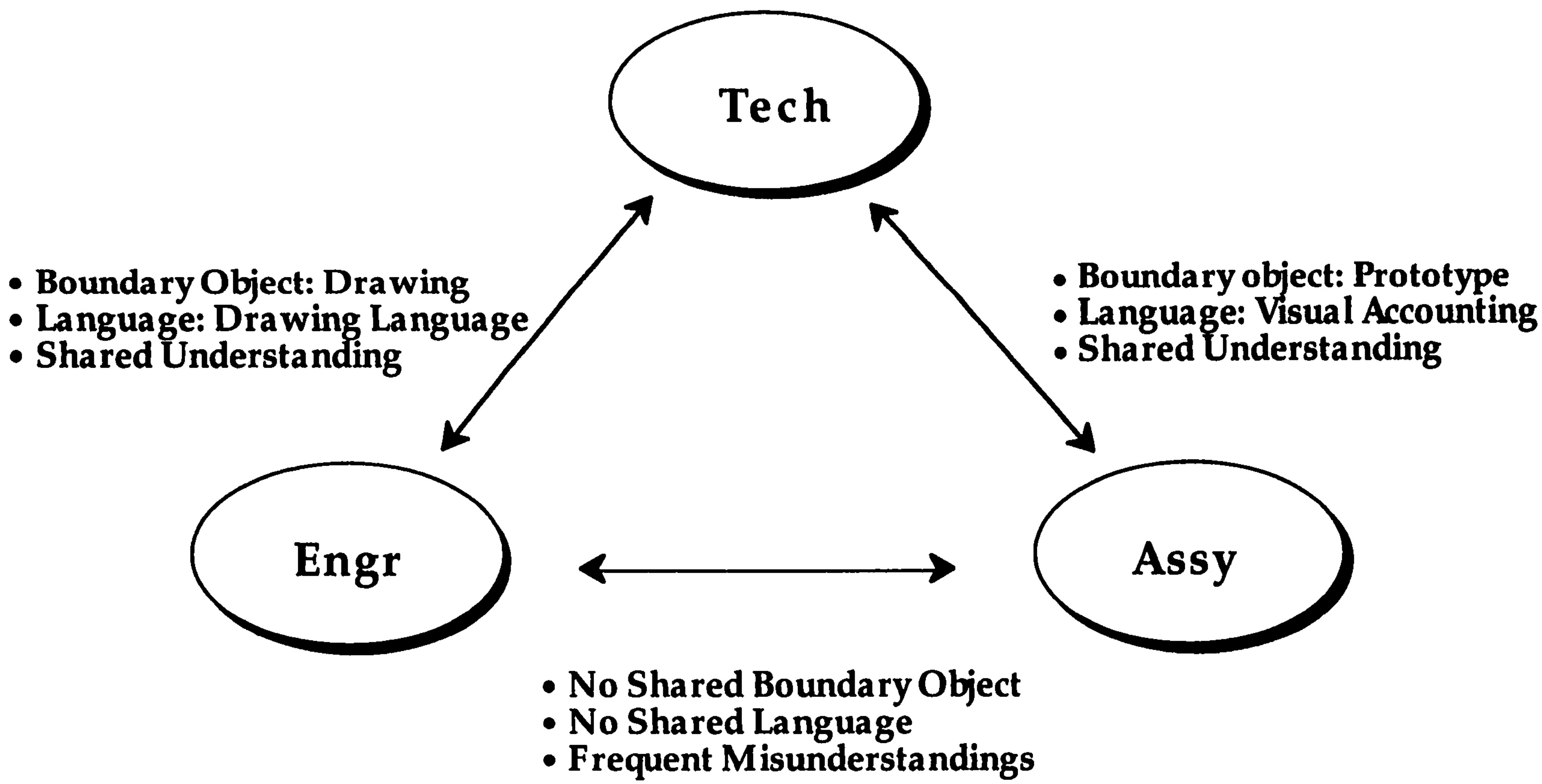
Wright, T. P.
1936. "Factors affecting the cost of airplanes." Journal of Aeronautical Science, 3: 122-128.

Yelle, L.
1979. "The learning curve: Historical review and comprehensive survey." Decision sciences, 10: 302-328.

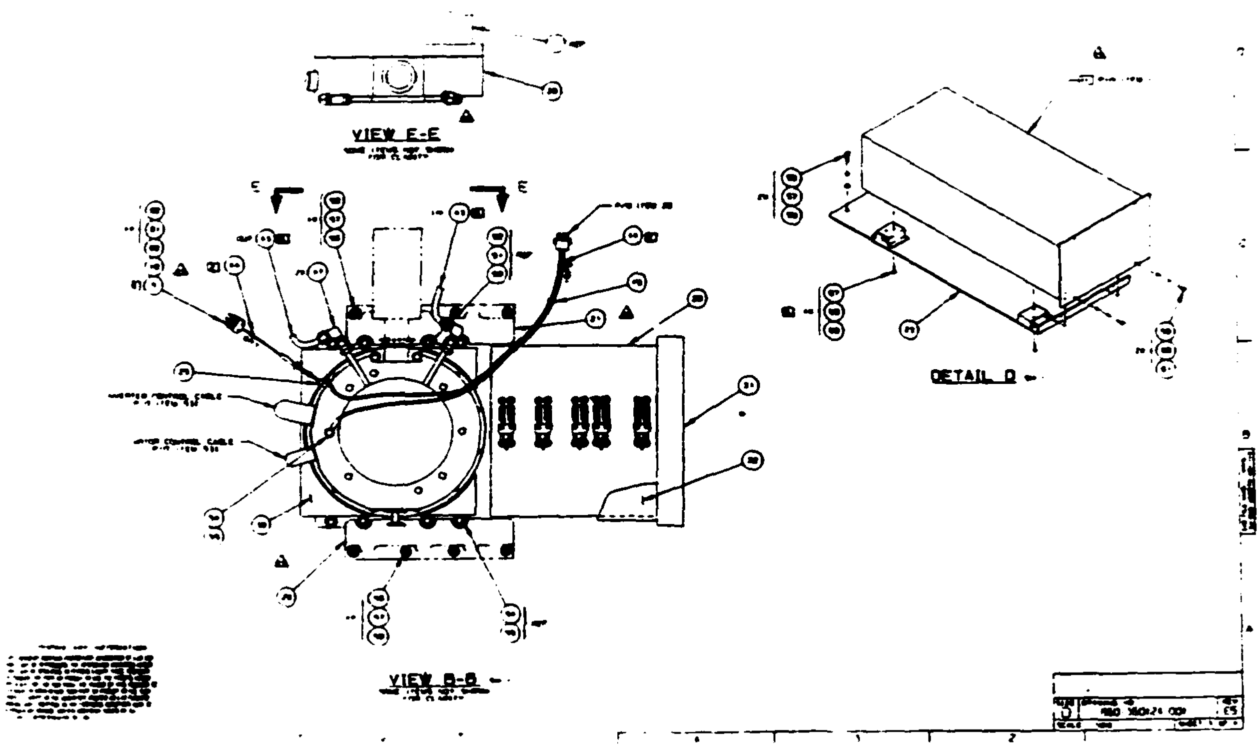
	ENGINEERS	TECHNICIANS	ASSEMBLERS
Knowledge in the body	Design work: How to create drawings Visualize inside of machine	Building work: "Get a feel" for machine Visualize building	Building work: Trial and error
Knowledge of the product	Machine: Theoretical Parts' functions Where parts should go Materials Drawing: All views and terminology How much detail	Machine: Bricolage Order of assembly Parts' functions Requirements of other groups Drawing: Familiar with notation/terms	Machine: Order of assembly Some parts' functions Clean room requirements Drawing: Cross-check BOMs
Knowledge of tools	CAD Manufacturing mgmt system	Had own toolbox Mechanical tools Manufacturing mgmt system	Shared toolbox Mechanical tools Manufacturing mgmt system
Knowledge of org. procedures	Correct and distribute drawings ECN process Parts ordering, inspecting	Get right parts and build properly Parts ordering, rework Who signs what Machine handoff procedure	None (Lead ordered parts)
Knowledge of the work role of others	General roles Reputation of others Suppliers	General roles Focused on own role/reputation	General roles Circumscribed view of own role

Appendix 1. Contextual knowledge of occupational communities

Appendix 2. Occupational boundaries



Appendix 3. Two versions of an install drawing: Engineer's (top) and technician's (bottom)



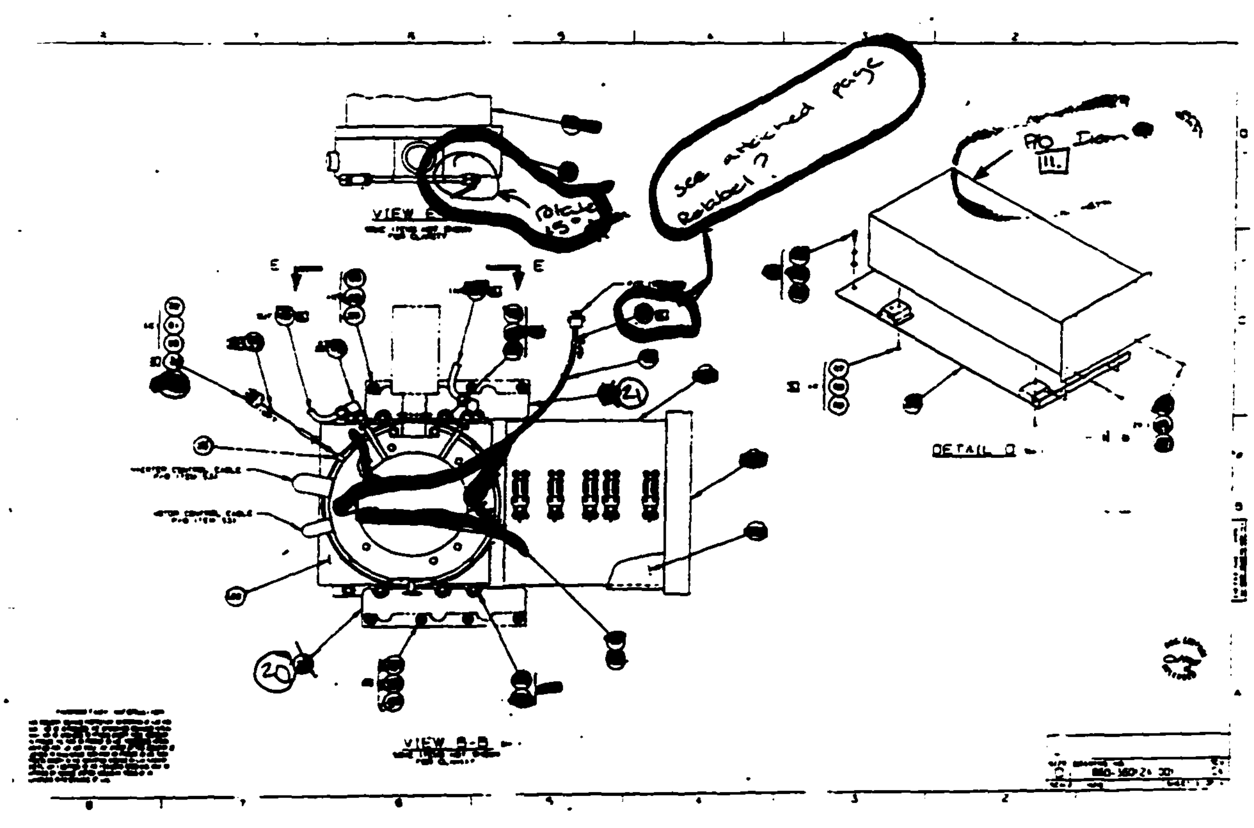


IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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