Sharing Meaning Across Occupational Communities: The Transformation of Understanding on a Production Floor

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Abstract
This paper suggests that knowledge is shared in organizations through the transformation of occupational communities' situated understandings of their work. In this paper, I link the misunderstandings between engineers, technicians, and assemblers on a production floor to their work contexts, and demonstrate how members of these communities overcome such problems by cocreating common ground that transforms their understanding of the product and the production process. In particular, I find that the communities' knowledge-sharing difficulties are rooted in differences in their language, the locus of their practice, and their conceptualization of the product. When communication problems arise, if members of these communities provide solutions which invoke the differences in the work contexts and create common ground between the communities, they can transform the understandings of others and generate a richer understanding of the product and the problems they face.
(*Knowledge Sharing*; *Problem Solving*; *Occupational Communities*)

There is increasing practical and theoretical interest in how organizations can manage, organize, and integrate knowledge. Because the number of knowledge workers is rising (Blackler et al. 1993) and knowledge has always been important to the functioning of organizations, the successful pursuit of these activities may create competitive advantage. In particular, in analyzing product development and manufacturing firms, industry watchers suggest that managing knowledge through the use of concurrent engineering and cross-functional teams will improve time to market, technology transfer, and innovation (Eisenhardt and Tabrizi 1995, Leonard and Sensiper 1998).

While research on product development has stressed the importance of cross-functional integration (Adler 1995, Wheelwright and Clark 1992, Clark and Fujimoto 1991), scholars and practitioners also recognize that integrating such communities can be difficult. Wheelwright and Clark (1992) suggest that all the different functional groups should be actively involved in the phases of development, and point out that a firm's choice of timing, frequency, direction, and medium of communication can affect the success of this integration. However, even in instances where communication is successful, creating shared understandings may still be problematic (Fiol 1994). Occupational communities, because of the specialization inherent in performing their own tasks successfully, have different perspectives on the work and the organization (Dougherty 1992, Boland and Tenkasi 1995, Carlile 1997). They also develop local understandings as a consequence of differences in expertise and experience (Jelinek and Schoonhoven 1990). The differences in perspectives across these communities can result in trouble sharing knowledge in a way that leads to greater understanding. Managers who want to capitalize on the coordination of diverse functions face the challenge of integrating the understandings of the different groups across the organization.

Much of the research that conceptualizes these challenges has emphasized general processes that organizations use to codify and transfer knowledge across boundaries. This work suggests that organizations use structures and processes such as routines and standard operating procedures to codify and transfer knowledge from localized contexts (March and Simon 1958, Levitt and March 1988, Huber 1991, Cohen and Bacdayan 1994). Other scholars have observed that successful knowledge transfer is not so simple, and emphasize that the tacitness of much knowledge often makes codification, transfer, and subsequent replication of routines and standard operating procedures difficult (Nonaka 1991, 1994; Nelson and Winter 1982; Kogut and Zander 1992). This latter perspective suggests the inherent "stickiness" of certain knowledge within localized contexts due to social and cognitive constraints (von Hippel 1994, Nelson and Winter 1982). For example, individuals may

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not be able to articulate the "how to" of an act even when they wish to do so (Polanyi 1958, 1967). As well, motivational and cultural constraints may further impede such transfer (Szulanski 1996).

Although this work has significantly enhanced our understanding of why knowledge management and integration is so difficult, it treats "knowledge" as a given. While theorists realize that the mechanical notion of knowledge transfer is a limited one, it persists in our thinking about knowledge in organizations, implying that communication of knowledge is a simple process (Reddy 1979). Conceptualizing knowledge in organizations with the impoverished metaphor of knowledge transfer has several implications. Simple knowledge transfer assumes a referential theory of meaning and implies that within organizations, meaning is universal and context is relatively homogeneous. Yet in practice, these assumptions do not hold. Even when knowledge is made explicit in a codified routine, when it is communicated across group boundaries, some organizational members may not understand it because they apply and interpret this knowledge within different contexts. In contrast, literature from numerous perspectives shows that there is an array of meanings in organizations: Understanding is situational, cultural, and contextual. The creation and enactment of organizational knowledge is therefore a complex process involving the understandings of multiple communities. In this paper, my approach is to advance our understanding of the implications of situated meaning for knowledge sharing by exploring how local understandings are reconciled through a process of transformation that assists the sharing of understanding across communities.

Alternative Perspectives on Knowledge Sharing

Underlying a metaphor of knowledge transfer is a referential theory of meaning: Written or verbal expressions of knowledge (such as standard operating procedures) have a single meaning to which they refer. Knowledge that is transferred is assumed to have the same meaning for both the person who expresses it and the person who receives it. However, as semioticians have pointed out, when one thinks of an expression as a sign, a variety of contents can be expressed by the same signifier (Barthes 1967, Eco 1976). For example, the word doctor might signify a surgeon in a hospital waiting room about to impart the news of a successful triple bypass, an image of a doctor on television, or the emotive connotation of care. This suggests that a particular expression of knowledge could potentially signify multiple contents. This poses a problem for the notion of knowledge transfer because if an expression of knowledge means something different to the receiver than it does to the communicator, then it is not clear what knowledge is being transferred.

Similarly, sociolinguists have demonstrated the importance of context for understanding language. Not only do words signify a variety of contents, but such contents depend on the situation, context, and community in which people are expressing themselves (Cicourel 1981, Blom and Gumperz 1972). When people assume they are speaking with other members of their speech community, they also assume a common understanding that influences their ways of talking (Garfinkel 1967). These understandings change depending on the community, and imply that the knowledge of one community may be unintelligible to another.

The reason that knowledge is particular to a community is that it emerges through situated activity; knowledge is constructed within a particular social context. As Lave (1988, p. 175) points out, "knowledge is not primarily a factual commodity . . . it takes on the character of a process of knowing." Because knowledge develops in relation to the activities in which people engage, what is seen from the outside as being the same activity actually takes various shapes as it unfolds in practice. Research on situated cognition illustrates the ways in which people's arithmetic practice, for example, is situated in their daily activities: Brazilian children solve math problems much better in the marketplace than they do with pencil and paper, and grocery shoppers also have more success with math at the market (Lave 1988). Knowledge in these studies takes on a very different character on the basis of the social context within which it is constructed.

Within organizations, knowledge is likewise constructed and situated. Multiple meanings emerge in organizations from various sources, including subcultures, occupations, functions, and networks (Perrow 1970, Weick 1979, Van Maanen and Barley 1984, Krackhardt and Kilduff 1990, Martin 1992). As a result of specialization and the division of labor, members of different occupational communities have different work experiences. Scholars who have studied these communities suggest that individuals make sense of organizational events from within the occupational context of their work and, due to unique work cultures (Van Maanen and Barley 1984), bring very different perspectives to their collaborative efforts.

Occupational communities are one important social milieu within which knowledge at work is situated (Orr

1990, Lave and Wenger 1990, Wenger 1998). Brown and Duguid (1991) describe the process by which learners in organizations are enculturated: They "acquire a particular community's subjective viewpoint and learn to speak its language" (Brown and Duguid 1991, p. 48). Lave and Wenger's (1990) idea of legitimate peripheral participation also suggests that communities strongly influence what individuals learn at work. As their research shows, individuals become members of a "community of practice," learning the appropriate work behaviors and norms as they increasingly participate in the group's activities. Participation in such communities, through means such as storytelling and apprenticeship, leads members to share common understandings of their world.

Participation in occupational communities also structures the organization of members' work itself, which has consequences for situating their knowledge. As Goodwin and Goodwin (1996, p. 65) illustrate in their study of airline operations, the work structure of the organization "defines a plurality of perspectives that entrain in differential fashion what alternative types of workers are expected to see when they look at an airplane." Through the course of their work, for example, baggage handlers and maintenance workers learn to "see" the planes and other work objects differently—Baggage handlers link the plane number with the flight on the schedule for which they are loading baggage, while maintenance workers link the plane with its maintenance history. The fact that each group sees the airplane properly, but differently, is an "ongoing contingent accomplishment within a community of practice" (Goodwin and Goodwin 1996, p. 87). Such situated work practice leads to the development of local understandings in organizations.

The image of knowledge presented by the literature on occupational communities depicts groups with strong subcultural understandings of their work. These subcultures provide a framework within which members interpret organizational events and their work world. As Schon (1983, p. 271) points out in his study of professionals' practice, these different frameworks mean that "the art of one practice tends to be opaque to the practitioners of another." Therefore, occupational communities within organizations can be expected to have different domains of substantive knowledge and heterogeneous ways of learning (Orr 1996, Van Maanen and Barley 1984, Boland and Tenkasi 1995). Such heterogeneous understandings belie the idea that transfer of knowledge between communities is simple.

Because the creation and enactment of organizational knowledge is a complex process involving the members of multiple communities, it is important to understand how the understandings of individual communities of practice are successfully communicated across groups. However, there is little discussion in the literature about the interaction between separate communities and the difficulties of sharing knowledge across boundaries and reaching a synthesis. Authors who examine occupational communities tend to limit their analyses to the practices of a single community, rather than investigate what happens when strong subcultural understandings need to be communicated among groups.

This paper advances the perspective that knowledge is shared through a process of transformation, not transfer, by analyzing the implications of occupational communities' situated understandings of their work for sharing knowledge between communities in organizations. In this paper, I link the misunderstandings between engineers, technicians, and assemblers on a production floor to their work contexts, and demonstrate how members of these communities overcome such problems by cocreating common ground that transforms their understanding of the product and the production process. In particular, I find that the communities' knowledge-sharing difficulties are rooted in their work contexts, which differ on the basis of their language, the locus of their practice, and their conceptualization of the product. When communication problems arise, if members of these communities provide solutions that invoke the differences in the work contexts and create common ground between the communities, they can transform the understandings of others and generate a richer understanding of the product and the problems they face.

Methods

Research Site

I conducted a year-long ethnography at EquipCo (a pseudonym), a semiconductor equipment manufacturing company located in Silicon Valley. EquipCo's 5,000 employees built the large and complex machines that other firms, such as Intel, use to fabricate semiconductor devices. Of these 5,000 employees, approximately 1,800 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 nontechnical administrative support such as planners and schedulers. In 1996, the year of the study, EquipCo's revenues surpassed $1 billion, and the firm was named one of the top 10 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 products were customized to meet the requirements of a particular wafer-fabrication facility.

EquipCo was an ideal site to study the dynamics of cross-occupational knowledge sharing. As a high-tech manufacturing firm that designed its own products, EquipCo had a strong formal organization, characterized by the importance of the distribution of engineering drawings. Additionally, EquipCo faced a quickly changing market, and therefore new prototypes were being built all the time. The many occupational communities involved in the production process needed to effectively share their knowledge to get these machines out the door. In a manufacturing organization, much of the feedback about the production process occurs during product "handoffs," when responsibility for the product shifts from engineering to prototyping to manufacturing. These handoffs provided many opportunities to witness the ways in which the informal social and work organization made the transformation of local understandings possible.

A basic description of EquipCo's production process is a prerequisite to understanding how knowledge was shared. The work of production at EquipCo progressed in phases, from design through prototyping and into final manufacturing. Each new product took from six months to a year to progress from inception to routine manufacture in final assembly. In the design phase, a team of engineers developed a new product, working together and using 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 the bills of materials and the assembly and install drawings that detail the design of the machine, and worked individually to complete them. The design process lasted from three to six months, depending on the product. Although the engineers met weekly for updates on each product and frequently visited one another's cubicles to discuss projects, engineers spent most of their time alone, and the engineering area was generally quiet and calm.

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 the engineering drawings and modified them. The technicians started building from scratch using the preliminary engineering drawings. Their work entailed making changes to the drawings and the machine itself as they discovered ways to make the product easier to manufacture. The technicians sat at benches in an open room, and built the machines on the floor space between their benches. With tools strewn across benches and parts piled up in boxes all over the room, the technicians' lab was a more chaotic work environment than was engineering.

After several prototypes were built and the engineers and technicians believed that the drawings were mostly correct, which was accomplished in two to three months, the assemblers were brought into the production process. Members of the assembly team trained in the technicians' lab, consulting with 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,[1] and they were told to use only the drawings as a guide to building the machine. However, they rarely used the drawings for guidance, finding it easier and more effective to ask the technicians or other assemblers for help, or to look at a prototype that was already built. After a one- to two-month training period, the assemblers felt comfortable building a product on their own, and they moved back into the final assembly area to build the machines. The final assembly area was in a clean room, an environment that mandated 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 could land on the machines and cause air leaks or other contamination. This environment was sterile, but loud and somewhat uncomfortable because the air circulation system in the spacious clean area kept the room quite cold, while the constant downdraft made it difficult for assemblers to hear one another, as did the hoods worn by every member of the team.

Data Sources

Because I was interested in obtaining the perspective of several different groups involved in the production process, fieldwork proceeded in several stages. My aim was to gather information about the work involved in the production of a new product, with a particular focus on the interaction between members of different occupational groups as the product was transformed from an idea to a prototype to an established product. I started my fieldwork in the technicians' lab, as this was the site for many of the product hand-offs in which I was interested, and this provided a base of understanding for the subsequent study of both assemblers and engineers. In all three areas, I gathered data from participant observation, informal and formal interviews, and documents.

Participant Observation

Technicians. I began my study at EquipCo by observing and working in the technicians' lab three to four days a week. The technician group was comprised of 27 members, 2 of whom were women. About one quarter of the group was Asian, Latino, or black. 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.

I first explained my role as a researcher who would be "hanging out" in the lab and assured the technicians that I would maintain confidentiality. Building rapport is not an instantaneous process; after several weeks of working in the lab, however, most of the technicians seemed comfortable with my presence. 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 person (a newly hired technician) said that he would rather not have me along as an observer.

My fieldwork in the technicians' lab comprised observing a different technician each day and working alongside many of them, building subassemblies and making cables. Over the course of the study, I spent at least two to three days with each of 26 technicians. Additionally, I cultivated relationships with 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, while teaching me skills ranging from soldering and reading engineering drawings to finding the quickest route to work in 6 a.m. Silicon Valley traffic. Most of the technicians also invited me to lunch and to bars and parties after work, and I often attended.

There were many other people circulating around the lab and interacting with the technicians, including design and manufacturing engineers, assemblers, schedulers, planners, and parts personnel. 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. As a result, I spent a bit more time in the technicians' lab than in the other areas because in this area I could gather data detailing the interactions of all three of the communities on a daily basis.

Assemblers. After a few months in the technicians' lab, two of my key informants among the technicians began the process of handing-off their projects to manufacturing. When the final assemblers that learned to build the two projects returned to manufacturing after the training period, I moved into the clean room with the six-person team. The assembly team had one woman, and all of its members were either Latino or Asian. 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.

My role as a member of this group never varied once they realized that I was willing to help and was relatively capable: I worked building machines every day for four months. Upon entering the clean room, we had fewer interactions with members of other groups. Occasionally a manufacturing engineer, manager, or technician came into the parts staging area (which was adjacent to the clean room and not particle-free) or called to ask a question, but very few people were willing to don a bunny suit to enter the building area.

Engineers. Having seen the transition from prototype to manufacturing, I was also interested in the transition from design to prototype. While working with the technicians, I had made the acquaintance of several design engineers, one of whom agreed to let me work with her for a few months. Of the 15 members of her team, two were women, and about 40% were Asian. 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.

I shadowed four or five members of the engineering team for two to three days apiece, although I spent the bulk of my time with the designer who invited me to join the group. In engineering, my role consisted mostly of observation rather than participation because most of the work was done on the computer, on the phone, or in meetings, and I was not qualified to help.

Interviews

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 involved in the production process, and I felt that I needed to clarify this use through more formal means.

I brought two sets of assembly drawings with bills of materials to each interview, and had informants 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.

Documents and Artifacts

Other important sources of data were the written material and objects that each of the groups used to support and perform their work. The documents included engineering drawings, bills of materials, and meeting agendas and notes. As mentioned above, documents, particularly drawings, were a key element in the production process, as they nominally served as the formal inputs and outputs for the different occupational groups in the study. I also closely studied the prototypes and products built by the technicians and assemblers.

Analysis

I followed a grounded theory approach of comparison and contrast (Glaser and Strauss 1967, Strauss and Corbin 1990) in analyzing the data. This approach entailed an iterative process of theoretical sampling, comparing and contrasting examples from the data to build theoretical categories which were then compared and interrelated to form the basis for this paper. I analyzed data and adjusted categories periodically throughout the fieldwork to confirm the test categories and further focus my study. At the end of the fieldwork, I reanalyzed field notes and the memos I had produced during the study to determine how the understandings and practices of the occupational communities differed, and the impact that this had on sharing knowledge in the production process. In this paper, I begin with a description of the work contexts of the three groups—the locus of practices, conceptualization of the product, and production process and languages that differed across these communities—and illustrate these context differences with examples of communication across the groups. Because of these differences in context, the groups could not simply transfer knowledge across their boundaries. Instead, organization members worked to create common ground, demonstrating their understanding of a problem in ways that could be integrated into the context of other communities. This transformation generated a more broadly shared understanding that allowed for the knowledge to be used across the organization.

Local Work Contexts: Locus of Practice, Conceptualization of the Product, and Language

At EquipCo, each occupational community represented a different work context with distinct understandings of the product and the production process. The key dimensions of the differences in work contexts—the locus of the communities' practice, their conceptualization of the product and process, and their distinct languages—are summarized in Table 1. The greatest contrast in context existed between engineers, who rarely touched or even saw the machines while focusing on drawing their designs; and assemblers, who spent all of their time building machines. The work context of these two communities lay within the separate spheres of design and production, while the context of the technicians, working between the other two communities, overlapped that of the other two groups.

These distinctions in work context were not always conspicuous during the everyday work of EquipCo, because the understandings of the three groups were also similar in many ways, since they all were working to produce the same products in the same company. Also, the technicians mediated the communication between the other two communities, which allowed production to proceed smoothly. However, the distinctions are key to analyzing how knowledge is shared at EquipCo, because they served as the taken-for-granted obstacles to the communities' understanding of one another. Analyzing these differences clarifies the causes of misunderstandings at EquipCo and creates a lever for determining how such obstacles are overcome.

Engineers' Work Context: Conceptual Drawing. The design of machines formed the essence of engineers' work; engineers created drawings for others to use in building. The locus of engineers' practice, or the core nature of the work they performed every day, therefore, was conceptual. Engineers' daily work entailed considering many representations of the product, envisioning in their heads, on computer screens, and on paper the machine-to-be. Engineers' practice was relatively distant from the physical product because they did not build the machine itself. Instead, they focused on designing a

Table 1 Key Differences in the Work Context of the Three Occupational Communities

	Engineers	Assemblers	Technicians
Work	Produce drawings	Build machine	Build prototypes and correct drawings
Locus of Practice	Conceptual	Physical	Conceptual and physical
Conceptualization of Product	Schematic: Form, fit, and function	Spatio-temporal and processual: How and in what order is the machine built?	Manufacturability: Will the machine work and can it be easily built?
Language	Engineering drawing language	Language of the machine	Engineering drawing language and language of the machine
Exemplar	"It's way more crowded than it looked on my screen!"	"This valve goes around the other side."	Assembler's "motor" reported to engineer as "harmonic cable"

new product based on their ideas about how to improve on the function and appearance of previous EquipCo products.

Because the locus of engineers' practice was the concept of the machine, their knowledge centered on creating drawings that would illustrate how the machine would look at each point of completion. Their conceptualization of the product and the production process, therefore, could be characterized as a schematic understanding rather than as a processual understanding. Engineers were most concerned with issues of form, fit, and function—Their goal was to design a product that worked and was aesthetically satisfying. While the process of building a machine was critical to the organization, knowledge about building was not emphasized in the engineering area.

As engineers' practice was primarily the conceptual work of design, engineers' encounters with and interpretations of the product were filtered through the lens of the drawings on which they spent most of their time. Their infrequent contact with the physical machine resulted in great surprise when they discovered that the actual machine did not look like the CAD package and the picture in their heads led them to believe that it would. For example, upon his first encounter with the product in the technicians' lab, one engineer who worked on the design exclaimed, "It's way more crowded than it looked on my screen!"

Engineers' conceptual orientation and their design knowledge of the machine were reflected in the language in which they communicated. Engineers trafficked mainly in the written symbols of the engineering trade, the drawings. As Henderson (1995) points out, engineers depend on drawings as both tools to solidify their ideas and as boundary objects to elicit feedback and buy-in from others. The engineers at EquipCo used drawings as their primary means of communication, often pulling documents out in the course of conversation, and they spoke the language of engineering documentation fluently. To engineers, the drawings precisely signified their ideas about the design and function of the machine, and engineers would often refer to the drawings as though they were talking about the actual machine. When an engineer said "the turbo pump," she was far more likely to be referring to an assembly drawing of the pump than to the pump itself. In this way, engineers' talk echoed the precise, standardized language of the drawings, and engineers only had a rudimentary understanding of the language of the physical machine.

Assemblers' Work Context: Physical Building. In contrast, assemblers' work was structured, physical, and concrete. The locus of assemblers' practice was the physical manipulation of the parts comprising the machine: Assemblers built in a clean room and followed detailed specifications that allowed them little discretion about how to build the final product. They worked with the machine in a hands-on manner, building small discrete chunks and installing them on a frame to create the finished product.

Assemblers' understanding of the product was grounded in the context of their concrete daily encounters with the machine, and their knowledge was colored by their view of the machine as a device that was built in a sequential series of subassemblies. As a result of this physical practice, assemblers conceptualized the production process in a spatiotemporal and processual manner. Building a machine was conceived as a process of creating larger and larger subassemblies which had to fit together spatially in a certain way and therefore could only be placed on the machine in a particular temporal order. Therefore, although assemblers were generally unaware of the specifics of how the machine should function, they were quite knowledgeable about where the parts belonged, how the parts fit together and, equally importantly, in what order they should be assembled.

Because assemblers used the physical machine rather than the drawings as a representation of the building process, they rarely referred to drawings in the course of conversation. Their language was embedded in the concrete context of building the machine, and depended on the physical reference point offered by the machine itself. Therefore, if an assembler referred to the "turbo pump," he was probably about to install it on the machine. In the course of their work, assemblers did not need to know the names of the parts of the machine, and in practice, assemblers frequently did not refer to the 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 would gesture and offer a description.

Because most of their talk occurred in the presence of the physical objects about which they were talking, assemblers communicated by constantly gesturing and watching one another move around the machine. 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." In interaction, assemblers often used what sociolinguists call "deictic terms" (Tanz 1980, Cicourel 1990), which are terms that link talk with its spatiotemporal and personal context and are used to point out or specify, such as the pronoun "this."

For instance, while two assemblers, Andrew and Abe, were building a chamber together, a bolt scratched the side of a lifter for the chamber, and they coordinated their investigation of the problem with minimal verbal exchange. Andrew pointed it out and said, "Uh, oh, it's a big scratch, it's all the way down." Abe looked at it and the two of them loosened the bolts on the frame and started to pull on the lifter. Andrew swung his arms upward, saying, "Let's see if it works, go up," and pushed the button to move the lifter upward. When it didn't move, he asked, "How come?" and Abe, pointing to the bolts on the frame, replied, "Because we tightened these, we need to loosen them."

This exchange typified the communication of assemblers: It contained very few spoken words, and most of the meaning was indicated through gestures and deictic terms.[2] In contrast with engineers, assemblers spoke only the concrete language of the machine, and understood very little of the conceptual drawing language. Assemblers' communication depended on the shared context of their concrete work building the machine, and was simpler when the assemblers physically interacted around the machine. This also is distinguishable from the communication of engineers, in which interactions were fixed around the drawings rather than the machine.

Technicians' Work Context: Spanning the Boundary Between Engineers and Assemblers. 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 labored at the empirical interface between engineering and manufacturing, translating the requirements of each group for the other (Barley 1996, Barley and Bechky 1994). Technicians took the engineers' conceptual representations and built concrete machines, and the locus of their practice, therefore, was both conceptual and physical. Their work required interpretation of drawings, which focused their practice more on the conceptual than did the work of the assemblers. At the same time, however, technicians' work building the new machines centered their practice on the physical far more than that of the engineers.

Technicians' primary responsibility was to generate the redlined drawings that illustrated the changes engineers needed to make to the documentation to improve manufacturability. Therefore, manufacturability proved to be the means by which they conceptualized the product and the production process; technicians had a sense that the design of the product was changeable, and their goal was to make sure the product worked while at the same time making it as easy to manufacture as possible.

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. For instance, engineers knew every part by its proper name, which they used to label the corner of every drawing. In contrast, when I asked technicians in the process of building a subassembly "what are you building?" frequently they would not know the official name of the subassembly, and would check that corner of the drawing to find out what it was called. However, they would know the part's general function and where it would be located on the machine.

Technicians' role entailed relating to both drawings and machines, and they therefore shared an understanding of aspects of the product and production process with both engineers and assemblers. While engineers and technicians shared a conceptual understanding of the machine through their design activities, technicians and assemblers shared the physical relationship that was rooted in building. This dual understanding allowed technicians to smooth the relations in the production process and ease the transition of the machine from an abstract idea to a concrete finished product.

These key distinctions in the work context across the three communities manifested themselves frequently in interaction between members of the different groups. As sociologists of science have shown, groups interpret technologies in different ways, based on the social contexts in which they encounter them (Pinch and Bijker 1987, Mulkay 1979). Similarly, at EquipCo, the differences in the groups' understandings of the product and process reflected the different contexts in which they worked and the manner in which they worked with the technologies of the machines and the drawings.

These distinctions are vital to an analysis of shared understanding at EquipCo, as they suggest the near impossibility of a simple transfer of knowledge between the three groups. As described above, the understanding of assemblers and engineers was quite different, and even the understanding of the technicians, while overlapping, was distinct from that of the other two communities. These understandings were important for accomplishing the work within this specialized division of labor and were taken for granted within each community. Therefore, when production flowed smoothly it was difficult to discern the differences in understandings across groups. However, when members of different communities needed to interact to fix problems that arose, these differences became apparent in the communication difficulties between the groups. Below, I describe such difficulties and then explain how shared understanding was reached through a process of transformation, in which the groups overcame the obstacles created by the differences in their work contexts through the creation of common ground.

Manifestation of Different Understandings: Decontextualizations

The lack of shared context and understanding of the product manifested in the manner in which each group communicated about the machine, drawing, or production problem. Because the engineers had a conceptual, schematic understanding of the machine while the assemblers had a physical, spatio-temporal one, they used different terms to describe the product. Similar to the functional groups in Dougherty's (1992) study of interpretive problems in the product innovation process, members of different communities at EquipCo also focused on different aspects of the machine and placed importance on different issues. These differences in context across the groups manifested themselves in a particular type of misunderstanding between groups that I will call a decontextualization. A decontextualization was the context-based use of different words and concepts to talk about the same object.

Decontextualization occurred when people from different groups met to discuss a problem, and brought different understandings of the problem to their discussion. 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 had a more static, schematic conceptualization of the production process while assemblers understood it spatially and temporally, even in situations where they were discussing the same machine, they often did not have the perspective and context that was required to understand the others' comments. In decontextualizations, the machine or situation was presented in language that was assumed to be universal and unproblematic, but in fact the words were incomprehensible to those who did not share an understanding of the context of the situation.

For example, one day in final assembly, an engineer, Evan, came to the parts room in the assemblers' area to ask Abe about some scratches and chips on the inside of one of the chambers. Evan inquired, "How did the chips get there?" Abe, gesturing upward with both hands, responded, "When you lift the plate, a screw gets caught." Evan looked puzzled. After repeating the words and gesture several times to no avail, Abe 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 Evan, pointing out the screw on the corner that moved and caused scratches inside the chamber.

The assembler, Abe, had begun by answering Evan's question without being able to refer to the machine, since they were outside of the clean room. The engineer did not understand Abe's response because he did not experience the same work context as the assembler. Evan lacked 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 Abe'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.

In these kinds of communication difficulties, different understandings of the product and process emerged from the work contexts of the communities. Engineers' understanding was fixed in the conceptual context of their drawing work while, in contrast, the understanding of assemblers centered on their concrete work building the machine. Both these understandings were necessary to create a working final product from an engineering design, but their divergent nature did not allow for the straightforward transfer of knowledge that is suggested by some of the literature on organizational knowledge and learning. Instead, the situated understanding of the groups had to be reconciled in some way that could allow for understanding to spread across the communities. This was accomplished through informal interaction between members of all the communities that resulted in transforming the local understanding of the groups to create richer, more broadly shared understandings.

Transformation of Local Understandings

While the technicians often discovered and contextualized discrepancies in local understanding during the course of their prototyping work, some problems slipped through the cracks in the production process. These problems interrupted the workflows of engineers, technicians, and assemblers, and brought together members of different occupational groups with different understandings of the product and the production process. The different perspectives that arose during these kinds of informal interactions around problems with the machine resulted in opportunities to transform understandings across the occupational communities.

Transformation. Transformation occurred when a member of one community came to understand how knowledge from another community fit within the context of his own work, enriching and altering what he knew. In transformations, an individual's understanding of the product, process, or organization was expanded, not merely by the introduction of new knowledge, but by placing that knowledge within her own locus of practice in such a way that it enhanced the individual's understanding of her work world, enabling her to see that world in a new light. As I will describe below, misunderstandings between the groups were reconciled through the use of tangible definitions to cocreate common ground. In the creation of common ground, the members of the groups were able to recontextualize local understandings, providing the context needed to create shared understanding across communities.

The ability of transformations to create broader, shared understanding can best be seen through an extended example. This example is summarized in Table 2, which provides several representative examples of the transformations that I saw at EquipCo. In this instance (Example 1), which occurred one afternoon in the technicians' lab, an assembler tried to translate the language of the machine for an engineer, but when it did not move the participants toward enriched understanding, he augmented it with a concrete example of the problem. The assembler, Arturo, and the lead assembler, Andrew, were helping an engineer with some details on the design of a fixture to lift the turbo pump. Edward, the engineer, said, "The fixture can lift it up about $8\frac{1}{2}$ inches." Pointing to the legs at the bottom of the pump, which was sitting on the floor next to the machine, Arturo asked, "Can these four feet be sitting there?" Andrew, the lead, clarified, "He's talking about the legs of the pump, can those fit on the fixture?" Edward wanted to know if they could install the legs afterward, but the assembler indicated not: "They have to come first." Again, the lead assembler expanded, "The pump comes down with the legs on, will there be clearance?"

After some more discussion, Edward, the engineer, returned to the issue of the legs, asking, "Can we take the standouts off?" Arturo, the assembler, said that it would be harder to grab the pump, and Edward replied, "But if you have the jack you don't need to grab it." "Then how will you get it *on* the jack?" replied Arturo, annoyed. Andrew 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 knew which parts fit where and in what order they needed to be assembled: He had a spatio-temporal, processual understanding of the machine. Therefore, he made comments such as "They have to come first," referring to the point in the assembly process at which the legs should be attached to the pump. In contrast, the engineer, Edward, knew how the machine was designed to work and had a conceptual understanding of how the parts should fit together: He had a schematic understanding of the machine. Edward did not have a contextual sense of the order of assembly, and he therefore did not understand much of what the assembler said. The lead assembler, however, realized that the engineer needed extra context and tried to translate 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.

This translation proved unworkable, however, because it was unable to invoke the elements of the work context

Table 2 Transformations

Event	Interactants	Prior Understanding	Manifestation	Reconciliation	New Understanding
(1) Turbo pump fixture	Engineer (Edward)	Fixture has to fit under turbo pump.	"Can you install the legs afterward?"		
	Assembler (Arturo)	Fixture has to fit under turbo pump when hands are also there.	"They have to come first." (Decontextualization)		
	Lead Assembler (Andrew)			"The pump comes down with the legs on; will there be clearance?"	
	Engineer (Edward)		"Can we take the standouts off?"		None
	Lead Assembler (Andrew)			Demonstrates by moving his hands around the pump on the floor: "Out here you can lift it up," and in the area where it will be on the machine: "But in there you can't." (Tangible definition)	Engineer and assembler together measure the distances they need, a long discussion ensues in which engineer asks assemblers questions about exactly what they'll need.
(2) Electrode slide	Assembler (Art)	Slide is part that physically slides.	"The slide has six holes."	Pulls out part and points to holes. (Tangible definition)	
	Engineer (Edward)	Slide is electrode slide.	"No, the slide has 10."		"Oh! That's on a different part, I thought we changed that part a year ago."
(3) Chamber chips	Engineer (Evan)	Problem with chips, doesn't know cause.	"How did they get there?"		"So now I know the cause."
	Assembler (Abe)	Problem with chips, knows the cause.	Gestures upward: "When you lift the plate a screw gets caught." (Decontextualization)	Returns with plate and demonstrates how the plate moves, pointing at screw. (Tangible definition)	"Now he knows, we've known for a while, but nobody listens to us because we're final assembly."

Table 2 (cont'd.)

Event	Interactants	Prior Understanding	Manifestation	Reconciliation	New Understanding
(4) Plasma starter	Technician (Tara)	Fitting should be at a 90 degree angle to the chamber.	Looking at drawing: "How did those fittings get reversed?"		"It figures. Okay, well just make sure it stays put."
	Assembler (Abe)	Fitting is in the right place.	"Tim (tech) says it goes this way." (Decontextualization)	Pointing at the part on machine, swiveling his hands: "When we got the part from vacuum, the entire block was reversed, not just the fittings." (Tangible definition)	
(5) Short cable	Engineer (Eric)	Cable should fit on machine.	"Can we attach the dash 57 cable?"		
	Technician (Tom)	Cables are down rev and will not fit.	"No, that isn't the right cable." (Decontextualization)		
	Engineer (Eric)		"Yes it is."		
	Technician (Tom)			"No, it's not. I don't think we have the right one here; they are all too short."	
	Engineer (Eric)		"Just attach it."		
	Technician (Tom)			Attaches the cable. (Tangible definition)	"Oh, no. And it also is right up against the manifold."

necessary to make clear to the engineer how the assembler's comments would have meaning for the way he designed the fixture. Therefore, Andrew gave a physical demonstration of the process by which the assemblers built the machine. This concrete example transformed the building knowledge of the assemblers, which had been expressed verbally in the language of the machine, via a physical demonstration of lifting the pump that the engineer could fit within the context of his own design practice. The engineer left with a more concrete understanding of the process by which the machine was assembled, which informed his design of this particular fixture as well as changed his conceptualization of the production process and how he would need to design other fixtures in the future.

Shared Understanding Through Transformation. In order to develop shared understanding between groups that had different work contexts, members of the groups had to cocreate some common ground (Clark 1996). Common ground is the "sum of mutual, common, or joint knowledge, beliefs, and suppositions" (Clark 1996, p. 93). Transformations created common ground by invoking the key differences in work contexts—the language, the locus of practice, and the conceptualization of the product and production process. Because the groups' understandings were rooted in these differences, only by bringing these differences to their attention could their understanding be transformed.

For instance, in the example above, simply trying to clarify the language differences did not help the engineer grasp the assembler's meaning. By physically demonstrating the problem, however, the assembler provided some common ground—He lifted the part that was familiar to the engineer from his schematics and demonstrated that in physically assembling the part, his hands would need to fit under the machine. This demonstration invoked both the locus of practice and the conceptualization of the product. The physical locus of practice of the assembler was visible to the engineer, who was able to relate that to his conceptual locus. Similarly, the assembler demonstrated the spatiotemporal and processual aspects of his conceptualization to the engineer, who could then build this understanding into his schematic conceptualization of the product. Making these differences visible and concrete created a joint setting where the engineer's understanding was broadened by incorporating an understanding of some of the elements of the assembler's work context.

At EquipCo, transformations frequently could not be performed verbally or through the written language of the drawings. In cases of decontextualization, the different languages caused muddled communication that made it difficult to come to a verbal reconciliation. Instead, individuals used tangible definitions, referring to examples that physically exhibited the problem,[3] to provide the means needed for members of other communities to come to a shared understanding. In this way, they recontextualized the problem and created common ground.

A tangible definition defined a problem with the machine 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 on the actual part in question, as the evidence in Table 2 demonstrates. For instance, one morning in final assembly there was a misunderstanding regarding a problem with the frame of the machine (Table 2, Example 2). Edward, an engineer, came to the door of the assemblers' lab and asked the assembler, Art, what the problem was. Art replied, "The holes for the slide don't line up." Edward 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?" Art corrected Edward, saying, "No, it has six holes." Edward disagreed: "No, 10." Art then went to the parts area and pulled the frame out of a box to show Edward the holes, and Edward realized that Art was talking about a different set of holes, not the holes for the electrode slide. To the engineer, the word "slide" connoted the formal term "electrode 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 concrete language of the machine: parts that physically slide. In this misunderstanding, the different languages of the engineer and the assembler were causing confusion. Further elaborating verbally could not solve the problem. Instead, a demonstration with a tangible definition of the part bypassed the language differences, using the physical locus of practice of the assembler to provide the context of the part for the engineer.

Similarly, in the problem with the chamber chips described earlier (Table 2, Example 3), the engineer did not understand the language that the assembler used to describe the problem. Additionally, the engineer lacked the knowledge of the assembler's work context, the spatiotemporal conception of the machine that would allow him to understand the assembler's gesture depicting the movement inside the chamber. The problem was recontextualized for the engineer by the assembler when he demonstrated with the part to which he was referring, which made the work context of his description clear to the engineer. The engineer did not understand the assembler's initial description of the problem, because his schematic conceptualization of the product did not contain the processual context of which parts moved where in the course of assembling the chamber. However, when the assembler brought over the plate that moved inside the chamber, the engineer had a concrete context in which to ground his understanding of the assembly process and link it to his schematic understanding of the design of the machine.

In this way, tangible definitions aided transformation by providing a physical touchstone, a demonstration that served as a basis for linking different contexts together. Tangible definitions allowed people to ground their divergent understandings in the physical world—essentially providing a concrete hook on which to hang their contextual interpretations. In my year at EquipCo, I saw many instances in which members of the engineering and assembly groups struggled to understand one another in conversation, only to immediately comprehend the other's point when it was expressed with a tangible object that both could place within their respective work contexts.

The prior examples demonstrated how tangible definitions can create common ground when language fails. Tangible definitions can bypass language difficulties by bringing the other elements of the work context, loci of practice and conceptualizations of the product, to the fore. However, even in cases where members of different occupational communities understood one another's language, decontextualizations still occurred. Table 2, Example 4 describes a situation in which technician, Tara, and an assembler, Abe, were discussing the fitting on a plasma starter. While they understood one another's language, Tara was confused as to why the fitting on the machine did not look like the drawings indicated it should. However, when Abe demonstrated on the machine, swiveling his hands to demonstrate what the part looked like when it arrived at the lab, Tara was able to place this tangible definition into her conceptualization of the product. She was concerned about manufacturability, and when Abe demonstrated in a way that showed how the fitting would be manufacturable as he had attached it, she was satisfied. As this example shows, the assembler and the technician shared a language and their loci of practice even overlapped considerably, and yet there was still a misunderstanding. Because the tangible definition invoked the difference in their conceptualization of the product, it recontextualized the problem for Tara in a way that created shared understanding.

Tangible definitions, as visible, manipulable representations, allowed members of different groups to interact with a manifestation of a problem. In these interactions, members of different occupational communities could place the object into the context of their own practice and manipulate it, thereby figuring out how it meshed with their conceptualizations of the production process. By enabling members of different occupational groups to manipulate them in this way, tangible definitions provide what Cook and Brown (1999) call "dynamic affordances." Dynamic affordances furnish the opportunity to learn about the world through interaction with it. Individuals' interactions with tangible definitions dynamically afforded new understanding by raising questions about what the objects allowed or constrained and how they might be used or manipulated. These types of questions would not be raised without the concrete object with which to interact.

For instance, in their interaction around the attachment of a cable (Table 2, Example 5), the engineer, Eric, insisted that the cable be attached despite the technician's assurance that the cable was a down rev (old) part that would be too short. Eric was concerned that the cables on his drawings accurately reflected their position on the machine. He was certain that his schematic conceptualization, in which the cable labeled "dash 57" fit on the machine, was correct. Eric had not spent time examining and attaching the cables, so he did not believe Tom, the technician, who had worked with the cables for the past several weeks and knew that they did not fit because they were old versions of the parts. Once Tom attached the down rev cable, however, not only did Eric understand the problem, but the physical manifestation of the problem sparked an intense discussion between the engineer and the technician regarding the other ways they could potentially route the cable and design the shape of the enclosure it connected.

At EquipCo, tangible definitions which invoked key differences in the work context helped to recontextualize these differences, creating the common ground for transforming understandings across occupational communities. Throughout the informal interactions in which transformation occurred, I witnessed the proverbial "Aha!" in the reactions of members of different communities. These reactions can also be seen in the last column of Table 2, which illustrates individual reactions to transformations. For instance, in Example 3, when the assembler demonstrated how the plate rose in the chamber, the engineer indicated, "So now I know the cause" of the chamber chips. Additionally, after transformational interactions, members of all communities frequently remarked upon what they had gained from the exchange. Here, the understanding of each community was broadened in a way that was useful for their future interactions and work. By exposing members of different communities to the perspectives and work of others, these interactions also reduced the differences in the understanding of the groups, making future work easier. Members of different groups grew to appreciate the expertise of others, and frequently carried this appreciation over into their future design, prototyping, and building activities.

Discussion

The use of tangible definitions to create common ground at EquipCo illustrates that the transformation of local understandings is vital to effective knowledge sharing in organizations. While examining knowledge transfer has been a fruitful avenue of inquiry, it has allowed us to persist with a somewhat mechanistic and simple conception of knowledge sharing that could be greatly enriched with a focus on the more organic conception of transformation. Demonstrating the process by which transformations occurred at EquipCo extends our understanding of how common ground can be created in organizations, points to how boundary objects are used in organizational learning and problem solving, and invites new ways of thinking about the perspectives of communities of practice.

Common Ground and Boundary Objects. The study of EquipCo demonstrated one way in which tangible definitions could serve as boundary objects between groups, creating the common ground that leads to shared understandings. Boundary objects are flexible epistemic artifacts that "inhabit several intersecting social worlds and satisfy the information requirements of each of them" (Star and Griesemer 1989, p. 393). While there has been some research on the use of objects at group boundaries for the purpose of obtaining goals and shaping outcomes (Carlile 1997, 2002; Henderson 1995; Star and Griesemer 1989; Leonard-Barton 1988), the development, use, and influence of such objects within organizations is not fully understood. The analysis of tangible definitions at EquipCo helps to clarify when and why boundary objects are useful.

For example, Carlile (2002) provides an informative typology of boundary objects that work at different types of boundaries: syntactic, semantic, and pragmatic. Specifically, Carlile's (2002) data shows that objects, models, and maps are the type of boundary objects that are most effective at pragmatic boundaries, where they facilitate transforming knowledge to deal with conditions of difference, dependence, and novelty. My research at EquipCo dovetails with Carlile's (2002) findings, but also suggests some additional conditions under which boundary objects will and will not work.

As Carlile (2002) points out, a boundary object such as a CAD model may be effective at one particular boundary, but fail when taken to another setting. The findings at EquipCo suggest that the reason such boundary objects fail is that they cannot be used to create common ground because they do not invoke the necessary elements of work context. For instance, while the machines at EquipCo frequently were used as tangible definitions, the engineering drawings were not. While the assumption at EquipCo was that the engineering drawings were the best communication medium, in practice, it was difficult for assemblers to use them. The language of the engineering drawings was too abstract, technical, and unfamiliar for assemblers to associate with their physical conceptualization of the product, since they lacked the understanding of drawings that comes from daily use. Because the drawings could not invoke the key differences in work contexts between the groups, they did not create common ground, and therefore were not useful as a boundary object between engineers and assemblers.

Therefore, while objects can be used to create shared understanding, and did so in some cases at EquipCo, they also can serve as a constraint. Similarly, because they inscribe not only knowledge (Latour and Woolgar 1979, Akrich 1992) but also social relations (Foucault 1979; Knorr-Cetina 1999; Latour 1988, 1996), objects can mobilize action in ways other than sharing understanding. For instance, elsewhere I describe how objects are used to legitimize work and maintain and challenge occupational control over task areas (Bechky 2002). On the production floor at EquipCo, while the machines were an object used for sharing understanding, the drawings were often a means to solidify status. While this was the particular case at EquipCo, in different settings one would also expect that people would mobilize objects in ways that both promote and inhibit understanding.

Additionally, there will be situations in which tangible objects will not be sufficient to create common ground. Tangible definitions worked at EquipCo because the concrete manifestations of the problems were meaningful to all the parties—They invoked the loci of practice and conceptualizations of the product that each group had. However, in other settings tangible objects might be unable to invoke such elements of the work context. At EquipCo, while the conceptualizations and loci of practice of the engineers, technicians, and assemblers were different, they all had the goal of producing the same product. In other organizations, members of different communities who are making a decision or trying to solve a problem might have such divergent conceptualizations or work practices that a tangible object could not bring them to a shared understanding of the situation.

For example, a university hiring a new dean for its engineering school has many communities involved in the decision making: the other administrators, the faculty, the industrial partners, even the students. These community members have different conceptualizations of what constitutes an ideal dean, and in many cases these conceptualizations do not overlap in a way that concrete examples would help clarify the problem. Therefore, even when provided with concrete examples—particular candidates coming to the campus and talking about their plans for the school—universities often have trouble hiring deans. Additionally, people are not always able to create tangible definitions of their problems; for instance, when an organization faces an abstract problem such as how to change its culture, one would expect that creating a concrete object to demonstrate that change would be difficult. The findings at EquipCo are bound to cases in which tangible objects are meaningful and the differences in elements of the work context between occupational groups are not insurmountable.

Organizational Learning and Communities of Practice. Thinking about the transformation process also gives us new insight into organizational routines. One suggestion in the literature has been that tacit knowledge causes barriers to learning, and therefore knowledge transfer will be accomplished more easily by making routines and knowledge explicit through codification (Nonaka 1991, 1994). While tacit knowledge is clearly an element of the work of occupational communities (Polanyi 1958, 1967; Kogut and Zander 1992), this study demonstrates that the manner in which people communicated impacted the incorporation of knowledge into the work of others. When a routine is made explicit, it is frequently codified in the language that is resident in the community of its origin. This language may be inexplicable to members of other communities. Therefore, while making routines explicit might work in some cases, it is the transformation of understanding into the new context that makes it possible for it to be used across the organization.

The manner in which these transformations happened also confirms the importance of an important trigger for organizational learning: tangible evidence of a problem (March and Simon 1958). As other research has illustrated, interruptions that punctuate everyday activity provide opportunities for change (Tyre and Orlikowski 1994); and the more painful, obvious, and catastrophic such interruptions are, the more likely it is that change will occur (Vaughan 1996, Burns and Stalker 1961). As Tyre and von Hippel (1997) point out, problem solving frequently moves to a particular physical setting to take advantage of such tangible evidence. However, in addition to confirming the importance of such objects, this study illuminates the reason why tangible objects are important for learning at the cross-occupational level. In attempts to share knowledge across occupational boundaries, written and verbal explanations frequently failed to make meanings clear. Because their languages emerged from different contexts, members of different groups had a difficult time finding common ground on which to base their conversation. This common ground was more frequently found in a tangible object, which provided a concrete referent that individuals could manipulate to embed the understandings of others into their own understanding of their work context.

This analysis of transformation of understanding within organizations also contributes rich insights into the interaction at the boundaries between occupational communities. While we have known for some time that communities of practice are important sites of learning, there has been little study of the practices that occur at boundaries between such communities. By looking at interactions between members of different communities, we see that the strong context of learning within communities can cause difficulties in communication across them. The evidence I have provided about how understanding is transformed to fit these contexts suggests that the ways in which knowledge is shared within communities might prove less effective at the boundaries between them. For instance, Orr (1990) found that stories were an effective way for Xerox technicians to share knowledge. However, such technicians already shared a strong work context within their community of practice, providing them with a great deal of common ground. In contrast, I found that verbal explanations often did not suffice to share knowledge across community boundaries. Instead, more concrete means were necessary to ground the knowledge in a different context.

The significance of informal interactions and concrete objects for cross-occupational knowledge sharing also suggests several practical implications for managing organizations. With a trend towards increasing amounts of knowledge work, coordination and learning in organizations may face significant future challenges. Organizations want to take advantage of the benefits inherent in differentiation of tasks, but the strong local understandings generated by such differentiation, while helpful for the work process within communities, can make organizationwide communication problematic. This study illustrates that interactions between members of different communities, while sometimes painful, can lead to enriched understanding, particularly when a tangible object is offered to ground the interaction.

Managers should recognize that multiple understandings exist across occupational communities and find ways to promote the interaction that would allow such understandings to move and broaden the knowledge of different communities.

The findings at EquipCo suggest that a strong focus on formal routines and procedures such as engineering drawings might be detrimental to problem solving in organizations. Managers should consider providing and supporting channels for communication and concrete solutions alongside formal processes. While engineers' design activities and assemblers' building activities are vital, organizations should encourage each occupational community to gain an understanding of the others' work, such as providing incentives to engineers to put on a bunny suit and head into the production area. Similarly, instead of holding meetings in a distant conference room, project teams of engineers and assemblers should meet around the product to allow them a physical referent to use in their interactions. Augmenting formal training regarding organizational standards and processes (which tend to be expressed abstractly) with concrete visual aids would further encourage these concrete communicative practices.

Similarly, these findings imply that organizations which implement technology-mediated work practices such as telecommuting or virtual teams should consider how their groups are going to communicate and solve problems. If a cross-functional team is meeting via a conference call, for example, my research at EquipCo would suggest that there will be many unresolvable verbal misunderstandings. Depending on the occupational groups involved and how much work context they share, meeting physically in a setting that would allow for shared understanding of work objects might be a more efficient way to communicate across the team.

Conclusion

This study described the process by which understanding is transformed across occupational communities, generating richer understandings of the product and production process within the organization. Looking in a grounded way at the process of transformation at EquipCo uncovered the actions that workers take to make organizationwide learning possible and demonstrated that simple transfer is not a good metaphor for such actions. A close examination of the practices of occupational communities illustrated the significance of local work context in the transformation of understanding in organizations.

The purpose of studying the production process at EquipCo from an ethnographic perspective was to discover the ways by which understanding spread from within occupational communities to others throughout the organization. In this setting, the machine worked as a tangible definition to transform understandings, in part because the three groups had a similar enough context as a starting point. In some ways, this similarity meant that the groups were even less thoughtful about their differences. On the other hand, the similarity most likely allowed for easier creation of common ground. This suggests that these findings may not generalize to cross-occupational settings where the groups are less similar. In other settings, occupational communities may have to find other means for creating common ground.

For instance, future research should consider whether different understandings exist in production settings that are organized into cross-functional teams. Since these teams regularly expose individuals to members of other occupational groups, the understandings of the team members may incorporate elements of the work of others, which would result in the need for different types of transformation. Similarly, how are understandings negotiated among nontechnical occupations? Examining the cross-occupational interactions in organizations outside of the manufacturing realm would give further insight into the knowledge transformation process.

Finally, approaching the study of knowledge in organizations from a perspective that suggests that knowledge is local and develops through situated action reminds us that meaning in organizations is heterogeneous. Given that we each construct our understanding of the world on the basis of our experience and interaction in it, the constructions we create will be different, and sometimes unclear to others. It will take some work to reconcile these differences.

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Endnotes

[1]While modifications to drawings were being incorporated into the CAD versions of the engineering drawings, assemblers, technicians, and sometimes even engineers worked with the "redlined" drawings. These drawings, called "redlines" because they were always edited

with red pen, were the most recently updated versions that were available on the production floor.

[2]Knorr-Cetina refers to a similar behavior among physicists as "optical induction" (Knorr-Cetina 1990), and describes their communication around a blackboard. One might imagine that this behavior occurs among many technical occupations in which individuals frequently refer to objects in the course of their work. At EquipCo, however, I witnessed this behavior primarily among assemblers rather than among engineers or technicians. While engineers often referred back to drawings, for example, they did so verbally, and used the precise drawing language more often than gestures and deictic terms. This may be particular to the setting I was studying; however, it suggests an interesting distinction that might warrant investigation in the future.

[3]A tangible definition is similar to what philosophers would term an ostensive definition (Wittgenstein 1953, Winch 1963), as suggested by an anonymous reviewer. Ostensive definition involves a demonstrative statement, a deictic gesture, and a sample, the object being pointed at.

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