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An Asset-Based View of Technology Transfer in International Joint Ventures

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Abstract

An asset-based framework of technology transfer is proposed, illustrated by examples from studies of two international joint ventures. The framework depicts the organization as a collection of embodied knowledge assets. Differences between firms result from the different combinations of embodied knowledge types that are used to accomplish the same ends. Technology transfer is the transfer of embodied knowledge assets between organizations.

Four concepts, Transfer Scope, Transfer Method, Knowledge Architectures, and Organizational Adaptive Ability describe important aspects of the transfer process. Transfer scope describes the extent of embodied information being transferred. Transfer method describes the approaches used to transfer the technology. Knowledge architectures describe types of knowledge assets the firms possesses, and the relationships between them. The organization's ability describes its ability to change its architectures over time. Technology transfer involves selecting the proper transfer method given the demands of the transfer scope, working within the constraints of the existing organization's architectures, and its adaptive ability.

Increasingly, firms are turning to cooperative agreements with other firms to share knowledge, develop products, exploit markets, or concentrate power, (Friedman, Berg, et al., 1979; Hamel, Doz, et al., 1989; Harrigan, 1988; Kogut, 1988; Ouchi and Bolton, 1987). This trend has been accelerated with increasing global competition. With cooperative work inevitably comes the necessity to transfer technologies or knowledge from one place to another. This is challenging when the technologies being transferred are part of the on-going operations of a firm, such as production technologies. This paper addresses the problem of how to transfer technologies between firms with different, yet mature technological bases. A framework is developed which explains important considerations in the technology transfer process, and implications of the framework are discussed.

INTRODUCTION

Technology transfer from one organizational unit to another can be broadly characterized as being either vertical or horizontal in nature (Zander, 1989). Vertical technology transfer occurs when a technology moves along its natural development lifecycle, for instance, from research and development through production within a firm (Cohen, Keller, et al., 1979; Ounjian and Carne, 1987; Souder and Padmanabhan, 1989; White, 1977). Horizontal technology transfer occurs when technology moves from a group in one firm to a similar group in another firm. This type of technology transfer is most likely to be important in mature industrial markets, or in markets where there is overcapacity because of competition for market share. Firms competing in such markets may merge as the industry concentrates, or seek to strengthen their position by combining complimentary expertise from several players. An example of such a pooling of talent is found in the NUMMI joint venture (JV) between General Motors (GM) and Toyota, where GM is seeking to develop production expertise using the Toyota method. An interesting distinction between horizontal and vertical technology transfer is that while vertical technology transfer must bridge differences between units within a firm, horizontal technology transfer must bridge differences between organizational, and possibly national cultures. Because of this, horizontal technology transfer may be very challenging for the firms involved.

For the purposes of this paper, technology is considered to be any form, material or social, in which knowledge has been embodied. This includes hardware, software, products, rules, procedures, organizational structure, and know-how or technical expertise. The reasoning here is that knowledge about repetitive actions is codified into forms which reduce processing effort or cost in the future. A good metaphor of this is the computer expert system, where the knowledge of experts or experienced workers is captured in a program that can be used repeatedly by non-experts or even machines. The same principle applies to many different forms of knowledge. For instance, a tool might be designed which performs processes done previously in several steps or perhaps by skilled craft workers. Rules of thumb become operating procedures, hand tools become machine tools, and new organizational groups are created to perform specific functions done previously on an ad hoc basis. All of these forms constitute knowledge that has been codified into forms which make effort more efficient or less costly. A broad definition of technology is important in discussing technology transfer because not everything that is transferred between two firms is necessarily hardware. In fact, our observations of technology transfer activities between JV partners suggests that the transfer of physical hardware constitutes only a fraction of all the different forms of embodied information that are shared.

The different types of technology discussed above are grouped in a category called the **Transfer Scope**. Transfer scope ranges from minor transfers like exchanging general information, to relatively more extensive transfers like implementing new operating procedures which can ultimately influence several different areas within the organization. The range in transfer scope is meant to capture the variation in difficulty encountered in transferring different technologies from one place to another.

How a technology is transferred from one firm to another is also important. There are several rich lines of research from which to draw guidance. One of them is the diffusion literature. In this paradigm, technology or information spreads through a population of potential adopters only after they have somehow come in contact with it. Contact with a new technology can take place when people function in information- or enthusiasm-transferring roles such as champions or opinion leaders (Chakrabarti and Hauschildt, 1989; Dean, 1984; Ounjian and Carne, 1987; Souder and Padmanabhan, 1989; Rogers, 1983), gatekeepers (Allen, 1977; Allen and Cooney, 1971), or other organizational roles that facilitate the spread of information (Kazanjian and Drazin, 1986; Roberts and Fusfeld, 1981; Jervis, 1975). Personnel transferred from one site to another serve as another form of linkage between organizational units (Allen and Cooney, 1971; Allen, Hyman, et al., 1983; Ettlie, 1990; Roberts and Frohman, 1978). Finally, linkages can also be formed by creating special technology transfer groups, standing committees, or procedures which facilitate the sharing of technology between different organizational units (Roberts and Frohman, 1978; Roberts, 1979). The methods and activities used in the transfer process are grouped in a category called **Transfer Method**. Implicit in the transfer method category is a range in the effort expended by using the various methods, since some methods naturally require more effort than others.

Often, the physical relocation of a technology from one place to another does not necessarily mean that it has been successfully transferred. At least two factors will come into play to determine whether or not a firm is successful in transferring and adopting a new technology. The first is related to the degree of similarity between the technologies both currently existing in the adopting organization, and those being adopted. This factor relates to the inherent compatibility of the new technology with the **Knowledge Architectures** of the adopting organization.

Complex technologies are often aggregated systems of smaller sub-components. The way the sub-components are organized and interact with one another defines the architecture of the system (Clark, 1985; Henderson and Clark, 1990). Knowledge that is embodied in various forms constitute the knowledge architectures of the organization. These architectures include the technologies, operating procedures, social and organizational relationships, or organizational structure. Knowledge architectures have both aset and structural qualities. Architectures are like assets because they are the firm's inventories of embodied knowledge. Architectures are structural because the all the systems in the organization are interdependent. The organization's various systems interact like a jig-saw puzzle and determine the specific (and perhaps tell-tale) approach it uses to solve design problems, interact with a certain type of customer, or produce a specific product. The organization's knowledge architectures assume their distinctive patterns over time as the organization meets new challenges in the market, develops new products or procedures to cope, or adapts to changing conditions (Kogut and Zander, 1992; Orlikowski, 1992). Such knowledge architectures are sometimes referred to as organizational routines (March and Simon, 1958; Nelson and Winter, 1982), and in the context of an organization's ability to implement new technologies, the organization's absorptive capacity (Cohen and Levinthal, 1990).

The importance of knowledge architectures to technology transfer becomes apparent when an organization tries to implement a new technology. Like substituting one piece of a jig-saw puzzle with a piece from another puzzle, trying to substitute a radical new technology into the existing architecture of an organization often meets with failure because the necessary relationships are challenged, or do not exist at all (Tushman and Anderson, 1986; Henderson and Clark, 1991). A common explanation for this is that the organization has too much inertia in the current systems that define and support its current technology (Nelson and Winter, 1982). More specifically, however, a firm develops problem-solving techniques over time that allow it to be more effective (Tyre, 1991; Orlikowski, 1992) or more ineffective (Katz and Allen, 1982) at acquiring certain technologies (see also Cohen and Levinthal, 1990). An organization's problem-solving approaches may be a reflection of the emphasis it places on specific areas of expertise in its staff members. Organizations also have cultural philosophies that influence their ability to adopt new technologies (Kedia and Bhagat, 1988; Tezuka, 1991; Aoki, 1990). Finally, every new technology implementation is subject to a political process which affects the decisions and outcomes of efforts (Thomas, 1991; Dean, 1989; Barley, 1986) and contributes to or detracts from an organization's ability to successfully adopt new technologies. All of these elements constitute the architectures with which any new technology must interact in the organization.

The adoption of a new technology usually requires that some modifications or adaptations take place to both the adopting organization and the new technology (Leonard-Barton, 1988; Pelz and Munson, 1982; Rice and Rogers, 1980). The second factor affecting an organization's ability to implement new technologies relates to the ability of the adopting organization to marshall resources to make adaptations as a new technology is adopted. This second factor is connected with the **Organizational Adaptive Ability** of the adopting organization. An important distinction should be drawn between the organization's adaptive ability and the organization's knowledge architectures. Knowledge architectures are relatively static structural relationships in the organization (in the short term, at least). The organization's adaptive ability is its ability to use its resources to change those architectures. For instance, a new technology may not interact well with the existing architectures in an organization, but the organization may be able to re-deploy its engineering or production staff to engage in engineering problem-solving and adaptation. In essence, it may not have the architectures necessary to support the new technology, but it has the resources available to create new architectures. This is a different concept than that argued by Cohen and Levinthal (1990) where an organization's pre-existing set of abilities do not change during the time scale elapsing in the adoption of a new technology, and therefore determine whether or not it will be successful at implementing the new technology. While it is important to recognize that an organization can only change so much in the short term, it is also important to recognize that it can still change somewhat.

Several elements determine an organization's adaptive ability. As was mentioned previously, if an organization has relatively more people than are required for normal operations (admittedly a rare occurrence these days), they can be redeployed for problem-solving or implementing new technology. Perhaps more important than just being able to assign people to work on new technology adoption is the ability to direct the specific skills that are required to solving the problem. This is not referring directly to the skill mix of an organization's employees, per se (that would be considered more of an inventory of abilities in the short term, so it would be better classified as an element of the organization's architecture), but to the way that people are deployed for problem-solving. For instance, an organization might have experts in a certain technological area, but if they are engaged in new product development, they might be of little help in new process implementation.

Finally, firms that experience strong production pressures may not have the resources available to implement new process technologies (Souder and Padmanabhan, 1989; Tyre, 1991). The problem is that an organization may be unable to stop its production long enough to introduce new technology because its production capacity may be close to or exceeded by its commitments to customers. On the other hand, an organization with excess production capacity is able to stop production from time to time for equipment replacement, modifications, experimentation, or trial runs.

The four categories just discussed are summarized in Table I. A elaboration of each, along with supporting data, follows.

Table I
Framework Categories and Descriptions

Category	Description
Transfer Scope	The type of technology or knowledge being transferred, which reflects the extent or magnitude of the knowledge being transferred.
Transfer Method	The methods, procedures, and techniques employed in the technology transfer process, ranging from communication to developing special organizational units for technology transfer.
Knowledge Architectures	The forms and functional relationships between the structures and artifacts in which knowledge has been embodied in the organization.
Organizational Adaptive Ability	The ability of the organization to commit or re-deploy resources to change existing technologies and architectures, so as to adapt them to the requirements of new technologies.

THE RESEARCH

An on-going research project is underway to identify factors involved in the successful transfer of technology. A variety of methods are being used to understand the process, including interviews, archival data, and longitudinal survey data. Two partnerships are currently being investigated. One is a newly-formed joint venture (JV), Polychem, involving three companies in a chemical-related industry. The product manufactured by the partners is sold to technically-sophisticated industrial customers who process the product further before it goes to final consumers. The companies are located in Germany, Japan, and the U.S. The German and American partners had been involved in mutual technology transfer prior to the formation of the present joint venture. The objective of this joint venture is to establish regional manufacturing capability for potentially all of the product types currently offered by each partner. Each site will also maintain an R&D center of excellence which will be a lead research center in the JV for certain areas of product and process technology. Part of the present effort includes the creation of a new production line in Germany to support both German and Japanese product lines. The second partnership has been in place for much longer, and is a collaboration between two steel companies, one located in Italy (Italsteel) and the other in Japan (Japan Steel and Foundry, or JSF). In this agreement, JSF has provided process technology and organizational expertise to Italsteel.

The data were collected through interviews and visits to sites in the United States, Germany, and Italy. The interviews were open-ended and lasted between one and four hours. Informants were interviewed if they were involved or had been involved in the transfer of technology or information from one site to another. For the Polychem project, Fourteen engineers, scientists, or managers were interviewed in Germany, including two from the Japanese partner and one from the American partner. Nineteen engineers, scientists, or managers were interviewed at the American site. Sixteen engineers or managers were interviewed at Italsteel in Italy. Several of the people have been interviewed more than once over a period of more than a year.

OBSERVATIONS

The four categories defined in the introduction are further described using the data collected thus far.

Transfer Scope

The scope of technology transfer is determined by how much and what type of a technology a firm seeks to acquire from another source. The "what type of technology" portion of transfer scope is really the form in which knowledge has been embodied. The "how much" portion of transfer scope is how much information is embodied in the technology. The two are actually related since a form of technology such as a piece of manufacturing equipment will almost always embody more information than could a fax communication. Transfer scope itself may be influenced by factors such as a firm's strategic or operational choices, the extent of its resources and assets, or the relative power of the various stakeholders involved in the transfer process. These relationships will be discussed in greater detail on other sections, however. The purpose of this section is to define the different categories of transfer scope, which are explained below.

General Knowledge The most simple form of knowledge transferred between organizations is general knowledge about a technology, process, or capability. The transfer of a general awareness of another partner's capability would not allow the recipient to reproduce for itself its partner's capability, but it would allow it to determine whether or not a cooperative relationship would be appropriate, or what type of technology is available for transfer. Typical questions that might be asked to acquire general knowledge might be: "What type of technology do you use to accomplish this task?", "How effective is it?", or "How does it compare with the technology that we use?".

Acquiring general knowledge about a partner's technological capabilities is often the first step in transferring a technology from one site to another. For instance, the effort to create a new Polychem production line in Germany was started when the Japanese partner wanted to begin producing some of its products in Europe. An investigation of the German operations revealed that an existing production line there did not have sufficient capacity or capabilities to produce both the German and Japanese product lines. Based on that knowledge, it was decided to construct a new line there. Much more detailed analyses have since taken place in the design process and several technologies have been transferred into that production line. In other cases, gaining a general knowledge of a partner's capabilities in certain areas has showed that little would be gained by trying to implement one partner's technology at the other's site.

Specific Knowledge The transfer of detailed or specific knowledge is the most frequent form of transfer observed at the firms. Specific knowledge is that knowledge which provides a firm the ability to reproduce (although perhaps with some effort) another's capabilities. Specific knowledge is an accurate codification, to the extent that it is possible, of the knowledge underlying the technology in question. The goal of the design of a new Polychem production line in Germany is to employ the best of the partners' technologies at each step in the production process, so extensive efforts have been made to understand who has the superior technology. In the process, volumes of detailed drawings and production data have been exchanged through the mail by fax transmission, and compared and contrasted in joint meetings. Detailed analysis of the exchanged data produced a hybrid of two of the partner's technologies. General knowledge of the types of processes used at each location, and their gross performance characteristics was not sufficient for this stage of the equipment design process. In instances involving very complex technologies, specific knowledge which involves detailed specification is the only way to accurately assess the capabilities of a particular technology. In most cases, however, the transfer of specific information is the backbone of a technology transfer effort.

Hardware Hardware is knowledge or experience in production or products that has been embodied into a tangible artifact. This includes machine sub-components, parts, software, the machines themselves, products, and entire production lines or plants. The transfer of hardware has an advantage over other forms of knowledge in that hardware can be physically re-located and its operating characteristics generally remain the same in different environments (unless some modification is made by the recipient).

Transfers of hardware may be accompanied by manuals or operating procedures, but they are not covered in this category. The reason for this is that a recipient firm may already have that operating knowledge, gained through its own operations, and is transferring hardware merely to parallel a partner's capability. Conversely, a firm may already have hardware similar to that of its partner, and just seeks to adopt new operating procedures without also transferring hardware.

There are several examples of hardware transfer in both the Polychem and Italsteel JVs. The first stage of the collaboration between Italsteel and JSF involved transferring plant technology from Japan to Italy. Since many of the hardware designs were to be identical at each site, exact copies of machinery could be shipped from Japan to Italy for installation. In cases where a local producer could fabricate the equipment, only the designs were shipped. In either case, little or no modification to the hardware was made since the two plants were designed to be similar. At Polychem, where there are somewhat larger differences between the technologies in place at each site, physical hardware is transferred less frequently. In cases where physical hardware has been transferred, for instance from Japan to Germany, some modifications have been necessary to adapt to existing production lines. Often, however, attempts are made to preserve as much of the original design as possible.

Behaviors Behaviors represent knowledge that is embodied in people's actions and interactions. Many of the sites studied are very enthusiastic to transfer behaviors because they are seen as a potential source of significant improvement in manufacturing performance. One American Polychem manager estimated that fifty percent of the potential improvement in his production yields could result by transferring operator behaviors from the Japanese partner. For instance, it takes the operators at the Japanese Polychem facility about one half the time to start up a production line as it does their American counterparts. Italsteel is trying to transfer Total Quality Management (TQM) problem-solving expertise from its Japanese partner. It transferred several engineers to Japan with the express purpose of learning TQM problem-solving techniques so that they could teach them to colleagues and subordinates upon returning to Italy.

Transfer Method

There are three basic approaches to transferring information. They are through communication in various forms, the physical transfer of embodied knowledge, and the use of organizational integrating mechanisms. The physical transfer of embodied knowledge amounts to little more than shipping an item from one place to another, so it won't be discussed at length. The communication methods will be discussed under the headings of Direct/Indirect Communication, and Personnel Transfers. Integrating mechanisms will be discussed under the headings of Roles and Bridges.

The selection of a specific transfer method will of course be determined by a variety of factors, including the scope of the transfer, the nature of the technology involved, and the relative expertise and resources of the organizations involved in the transfer. The influence of these factors will be discussed after they have been introduced more formally.

Direct/Indirect Communication Direct and indirect communication encompasses the most basic types of communication behaviors, which include telephone conversation, mail correspondence, video conferences, and electronic mail and fax transmissions. Direct communication uses the spoken medium and may include telephone conversations or video conferences. Direct communication occurs in real time and allows for immediate feedback between the participants so that understanding of concepts can be assessed. Unfortunately, direct communication is limited in the amount of information it can communicate. Indirect communication, on the other hand, takes place through the written word, graphic representation, or a material object. It is able to transfer a lot of information (its one "picture is worth a thousand words" of direct communication), but has no immediate feedback to indicate whether or not the receiver understands what is being communicated. Indirect communication is especially useful in conveying information which measures or quantifies identifying characteristics of a technology. Using written language to communicate also is helpful where there is a difference of language. Many engineers read a second language better than they speak it, especially when they aren't under pressure to respond in real time. Direct communication is somewhat better than indirect communication at building interpersonal relationships and conveying enthusiasm between people, although it is still an arm's length relationship that is being encouraged.

At the Polychem joint venture, much of the technical information flows between the sites by direct/indirect communication methods. Once two partners have agreed to an exchange around a specific technology, detailed lists of questions about the technology are exchanged between the partners. The respective experts at each facility provide answers to these questions for their overseas colleagues. The detailed answers are traded, and follow-up questions are then asked, usually by fax or mail. All of this activity may culminate in a visit to a partner's site for intense discussion about the technology (at which time some information is transferred through the exchange of hardware, products, or materials samples, and by joint problem-solving). However, a large amount of preparatory communication takes place prior to one of these visits. For example, for one trip by a delegation from the American Polychem to the Japanese site, the equivalent of a large notebook full of documents was exchanged by fax between each partner beforehand.

The fax has become a preferred method of communication at Polychem because of the three different languages spoken by the partners. Another important advantage of using fax transmissions is that they can be sent at all hours of the day or night without regard for the local time of the destination. The advantage offered by the fax is that text can be replaced by numbers and figures, which have universal interpretability to those who speak the common technical language. The Polychem partnership is beginning to use video conference technology, which potentially offers all the advantages of the short-term visit (including a walk through the plant with a portable camera) but at a fraction of the cost. One American manager is very excited about the potential of the system to facilitate inexpensive technology transfer. However, a German scientist is somewhat less sanguine. He says that a video conference is probably better for managers than for specialists like him because the characteristics of the system allow one to cover issues with breadth much better than with depth.

Personnel Transfers When using direct or indirect communication methods, one must choose between having feedback or being able to communicate a large volume of precise of information. Transferring people from one site to another overcomes that tradeoff, albeit at a greater cost. Site visits allow face-to-face interaction with others and direct contact with several different forms of information. For instance, an engineer may discuss the operating characteristics of a piece of machinery with another engineer, inspect documents detailing its performance characteristics, and observe it in operation all at the same time. Face-to-face interaction at meetings like this is also associated with the development of interpersonal relationships which can facilitate future interaction (De Meyer, 1991). Short-term visits may range from a few days to a few weeks, and they are oriented towards accomplishing a specific goal. On the other hand, a long-term transfer may last several months or years and the goals are less well-defined.

Partners in the Polychem JV have found that engineering teams transferred to other sites for between a week and a month can be very effective at learning about a partner's technology. First, these teams are very focused in their objectives and generally quite a bit of preparation has gone into the visit to maximize the learning during their stay. They can observe also the technology at a level of detail impossible using arm's-length communication methods. This is especially important because if the partners have similar capabilities to begin with, the advantages gained by cooperation will be found in the details of operations. More importantly, while there the teams can observe the technology in the context in which it operates, and its interaction with other systems in the organization. This is important if the technology must be modified before it can be implemented back at the home site (there will be more discussion of this in a later section). The teams are able to work closely with their colleagues at the other site on specific technical problems, with immediate feedback on results so that efforts can be re-applied in other areas if necessary. This method also helps to form relationships between technical experts, and transfer enthusiasm for specific technologies across boundaries. Since this method is generally less expensive than longer-term transfers (lasting a year or more) of a single expert, more of the people who work with the technology on a day-to-day basis can experience it first-hand in the other setting, and they can gain a more in-depth and objective understanding of its strengths and weaknesses.

The Japanese Polychem partner was able to transfer some of its polymer formulation expertise to its German partner through short-term visits and indirect communication. The knowledge itself was embodied mostly in chemical formulae and process parameters, and was transferred readily. However, the direct interaction gained through site visits allowed the Japanese partners to emphasize cleanliness in the production environment rather forcefully. In one case, one Japanese engineer found that it was necessary to spend an entire day demonstrating to employees at the German site the cleaning of the polymer handling equipment and the levels of cleanliness required in the process. Such demonstrations would be difficult to communicate by fax, and the working conditions would probably have gone undetected had the Japanese engineer not been there to observe them.

Long term transfers are defined here to occur when an employee is transferred abroad for an extended period to learn about another's operations. Sending a student abroad accurately describes the engineer or manager on a long-term transfer. Often, long-term transfers are a step in the management development or training process. For instance, the American and German Polychem partners have had a policy that all R&D managers have to spend at least a year abroad in other operations in the company. The Italsteel engineers who were sent abroad were carefully selected and identified as high-performers, to be given operations manager positions on their return. This approach allows the managers to learn about a partner's or subsidiary's operations abroad so that there can be more coordination of efforts, as well as allowing them to be in a position to implement that knowledge in their home operations. People working together for an extended period also are able to form personal, trusting relationships. One Italsteel engineer found that where the rest of his colleagues were denied access to certain information or plant operations at JSF, he was able to gain access to that information and those areas because of his personal friendship with one Japanese engineer there. Personal relationships also lead to continued communication once the transfer assignment is completed (see Allen, 1979). One American Polychem manager who spent one and a half years in Germany still maintains regular contact with his colleagues there and still has a considerable amount of influence there even though he returned to the U.S. some time ago.

One disadvantage of long-term transfers is that they are expensive. Additionally, arrangements must be made with foreign governments for work permits, and meaningful work must be found for the person being transferred at the new site. Housing, language training, and assigning a "guardian angel" (a local employee entrusted with helping the newcomer) to help that person adapt to a new culture all add to the costs. There is another potential disadvantage with long-term transfers. That is in trying to repatriate the employee and capture benefits from the learning experience back at home operations. In cases involving both Polychem and Italsteel, sending managers abroad has not resulted in significant technology transfers back to the sending organization. Managers have complained about returning from an assignment abroad with ideas about how their own operations could be improved, but were unable to make changes. Several reasons were given for this. First, some could not transfer the enthusiasm they had for new technologies to others, because they were the only ones to have seen them. Or, the types of changes they recommended were too radical for the existing organization to accept. Finally, the responsibilities from their new jobs left them with little time to worry about implementing new technologies. The latter two points will be discussed in depth later. One final disadvantage with long-term transfers is that the technical experience of the engineer or scientist is sometimes lost as they are promoted into management positions. For instance, the German partner in Polychem is losing its foremost R&D expertise in a specific product area because it has transferred its key scientist in that area to Japan, and on returning he will assume a management position in the corporate offices. The same has already happened to an American engineer who was transferred to Germany. Even when returning engineers are not promoted into management positions, the technology at their home site will likely have evolved in their absence, and it may take some time for them to become current with it again.

A potential solution to the problem of capturing benefit from long-term transfers was observed by Italsteel engineers at JSF. They noted that JSF has a dual career ladder, with tracks for line managers and the technical staff. Line managers are primarily responsible for meeting production demands, while staff engineers act as internal process engineering consultants and are concerned primarily with process improvement. At JSF, the staff career ladder has a higher status than does the line management ladder. Engineers who have been sent abroad to learn are rewarded by being assigned to the staff career ladder when they return. This way the knowledge they gain in other organizations is not lost by them having to divert their attention to meeting production demands. Nevertheless, at Italsteel the majority of engineers sent abroad have been promoted to line management-type positions.

Roles An employee functions in a technology transfer role if any of the transfer methods described here are part of his or her designated work routine. People employing those transfer methods on an ad hoc basis would not be considered to be functioning explicitly in a technology transfer role. These roles form links between organizations or groups and facilitate the flow of technology or other forms of information, and so they are considered to be an integrating mechanism.

The most common transfer role observed is that of the communication node or gatekeeper. Gatekeepers are the focal points for much of the communication that flows between the sites. Factors which determine whether or not someone functions as a gatekeeper include managerial or project responsibilities, technical expertise, or superior language abilities. The latter factor is especially cogent in communications to and from the Japanese sites. Engineers in Japan who speak the best english are often the nodes through which most of the communication flows.

The second role observed is what is referred to at Polychem as a bridgehead. A bridgehead is someone who is transferred abroad for an extended period (a long-term transfer) to serve as the eyes and ears of the home organization abroad, to serve as a gatekeeper for communications flows, to engage in engineering problem-solving, and to assist teams from the home organization during their short-term visits. The bridgehead role is distinguished from the long-term transfer in that these responsibilities are a specific part of the objective of the transfer, rather than just learning about the other organization's operations or developing future management abilities. A bridgehead is a more active link between two organizations than is the "student" in the long-term transfer.

All of the engineers transferred away from their home operations in both the Polychem and Italsteel cases reported that they functioned as communications nodes between the organizations. They also serve as filters to communication. For instance, at Polychem in Germany, Japanese engineers working there use their own knowledge of the Japanese operations to answer questions before they are sent on to Japan. Even if the question can't be answered completely, it can be reduced to its essential elements and posed properly. In the past, the German engineers and scientists reported having problems framing questions properly so that they and their Japanese colleagues were working with the same understanding. This is not a trivial problem. One Polychem engineer noted that behaviors he and his colleagues originally attributed to being a strong case of "not invented here syndrome" or rigidity on the part of their partner was in fact due in part to different (and somewhat incompatible) styles of interacting and sharing information.

Since bridgeheads take an active role in the work at their new site, they offer a window into the expertise of the partner. Japanese engineers in Germany spend several hours each day working directly with design engineers there on detailed component and part design for the new production line. The bridgehead links two organizations together by transplanting the knowledge and understanding of one organization (as embodied in the employee) into the environment of another.

Bridges Bridges are procedural or organizational mechanisms which facilitate the flow of technology. Like a bridgehead, a bridge places knowledge or technology from both organizations in a common environment. Bridges are more complex than a bridgehead because organizational procedures or structures are set up to form that common environment, instead of simply transferring a person to another site. For example, Polychem has established common product quality measurement standards between all three partners so that direct yield comparisons can be made between the different production lines and process technologies used. The need for a common performance measurement system became evident especially in the early Polychem efforts to improve output quality. While each partner has similar process equipment, they have different ideas about what factors influence product quality. Consequently, they also have different process measurements at each site which impedes troubleshooting efforts. In some traits, production lines are unique. Comparing one with another sometimes requires that chemical feedstocks be transferred to another site to be processed allowing the output of the different lines to be compared. These integrating procedures ensure that a common language is spoken between the partners and a common basis for comparison and evaluation exists.

Italsteel engineers observed that JSF engineers have regular meetings in which they describe their solutions to problems they have encountered. They use a standardized engineering reporting system to form a bridge between the different engineering groups. In it, engineering reports follow a standard format that emphasizes brevity, conciseness, and the graphic display of data. These reports are collected and catalogued in a centralized library, so that engineers from throughout the organization can access them if future problems arise. This is opposite to the system used at Italsteel, where engineering problem-solving is often not well-documented or becomes lost in someone's files, so that the information is not available if problem arise again. Even when reports are available to others, the Italsteel reporting format produces reports that are very long and difficult to read (and seldom read).

Important bridges are the organizational groups whose express role is to integrate information from many sources and re-route it where appropriate. For instance, Polychem has standing committees composed of members from all three sites that coordinate strategic planning and R&D work on a global basis. The committees meet regularly to review and coordinate product development efforts, with the goal of trying to spread the benefits of research done at each site to the other sites if possible. Individual partners also have standing technical councils in specific areas, that integrate information from different functional disciplines, business units, or sites. In this latter case, the committees function as a gateway through which information from the other partners can flow into the organization and be routed to appropriate functional disciplines or business units. The American Polychem partner also recently formed a committee specifically to integrate information that has been collected through several different efforts, so that it can be better coordinated and disseminated within the organization. Many of the people attending the first meeting of the technology transfer committee knew that several efforts were underway to learn about partners' technologies, but they were amazed at the extent of the learning thus far, and the potential for spillover benefits to different operating groups. This was because there had previously been no common forum for sharing that information.

Knowledge Architectures

One of the Japanese Polychem engineers working in Germany commented that it was difficult to transfer technology from Japan to Germany because the approach to production in Japan is designed around Japanese workers with their particular work behaviors and attitudes. He found the German Polychem workers were sufficiently different from Japanese workers that technology couldn't be transferred without some modifications. This is an example of the interdependencies that exist between different organizational systems (which we refer to as knowledge architectures), which affect the transfer of technology. Architectures are the forms and functional relationships between the structures and artifacts in which knowledge has been embodied in the organization. They are knowledge that has been codified into technology, rules and procedures, or organizational structures.

Architectures have a dual nature, one stock-like, the other structural. Architectures are stock-like because they are the firm's inventories of embodied knowledge and reflect definite quantities or levels relative to other firms. For instance, a firm might have a technological capability in a certain manufacturing area, as represented by its production performance levels. Architectures are structural because the all the systems in the organization are interdependent. For instance, a firm's production performance levels are closely linked to that firm's approach to hiring and training, job design, the types of technologies used, and its past experience in that area. Technology transfer inevitably changes a firm's architectures because it changes both the inventories of knowledge and the relationships with other systems. In essence, the physical transfer of a piece of hardware may be straightforward, but its ultimate success depends on its fit with the rest of the firm's systems. Several of a firm's architectures can influence technology transfer, four of which will be covered below.

Hardware The more similarities in the hardware at each site, the easier it will be to transfer technology between sites. Technology transfer at Polychem has been made much easier by the fact that all the partners are working with a mature technology and that each partner's technology shares a common technical ancestry. The similarity means that teams from one site can visit another facility for a period of just a few days and gain a fairly detailed understanding of what technologies are being used and how they affect product characteristics. Rather than having to describe the technology in detail, details about equipment and processes can be described in terms of differences between them. For the same reason, hardware can be transferred readily and may only amount to replacing components in a piece of equipment or a segment in a line. Finally, if the hardware is similar, then more effort can be put into learning about a partner's operating procedures or problem-solving behaviors.

An extreme case of compatibility or overlap between sites would be found in the case of a clone plant. The Italsteel plant was designed to be a sister plant to one operated by JSF. During its initial construction, much of the technology was either transferred physically from Japan in the form of hardware, or was produced locally under license. In the latter case, the technology was transferred using blueprints and technical specifications, with some short-term visits and long-term transfers from JSF engineers. Since the Italsteel plant is now nearly identical to that operated by JSF, many of the problems that develop at the Italian works can be solved by telephone or fax communication with engineers at the Japanese site, usually without the need for travel. The opposite is true for some technologies at Polychem. The German and Japanese polymer production technologies are similar to each other, but quite different from the system used by the American partner. Many of the other production technologies have been designed around the specific core polymer production technologies used at each site. This means that some of the suggestions that Japanese engineers have made to the Americans on how to improve product quality depend indirectly to their own type of polymer production system. To use that advice would require changing several systems in the production line, at great expense. Consequently, the American partner is limited in the type of assistance it can receive from the other partners in this specific area of technology.

Procedures Procedures are the formal or informal rules of operations that define the way routine effort takes place in and is coordinated throughout an organization. They can be a source of significant competitive advantage if they make the interactions between people and technology, for instance, more efficient. For this reason, all of the sites visited so far have been trying to transfer procedures from their partners. But procedures also have an architectural nature because they are often closely related to the technologies, worker skills, or other architectures that differ from organization to organization. For this reason, procedures being transferred from another site may conflict with the new organizational environment unless either the organization or the procedures themselves (or both) are modified. For example, an Italsteel engineer who had been transferred to JSF commented that he had trouble implementing JSF TQM procedures at Italsteel because of fundamental differences between the two organizations. He said that the people at JSF view their organization as an information generating and processing structure, where people at every step in the operations produce and process information, and then furnish it to others in the organization. Production employees at Italsteel don't have similar procedures or training for producing and using information. Furthermore, information that is produced often isn't shared with others, nor is it sought after when it is produced elsewhere in the firm. In this case, the JSF procedures were in direct conflict with existing procedures, the experience base, and the power structure of Italsteel.

Italsteel engineers also observed that JSF workers were involved in the formulation and writing of their operating procedures. The Japanese Polychem partner uses the same approach. In both cases, engineers from other sites observed that there was a dramatic difference between the Japanese procedures and their own (which typically are written by engineers). The procedures written by the workers were short, concise, and included only relevant information. They were clearly written to be used. But they were also written by experienced users. The Japanese Polychem partner relies heavily on worker expertise to attain quality and output targets in the production process, so the workers have a lot of expertise that is relevant for writing procedures. On the other hand, at the American and German Polychem operations, relatively more emphasis has been placed on the role of technology to attain quality and output targets, and less on employee skills. Therefore, at these sites, workers have relatively less expertise to contribute to procedure formulation.

Adopting a new procedure may mean making changes to existing architectures in what can be a difficult and time-consuming process. Italsteel engineers adopted a JSF data log sheet to record production process data. The JSF log sheets were noticeably clearer and easier to use than the ones used previously by Italsteel. Even so, the Italsteel workers were not used to logging process data on a regular basis. For the space of a few months, an Italsteel manager had to strictly enforce that workers fill in the log sheets in an accurate and consistent manner, before the workers finally began to comply. The same thing happened at the U.S. Polychem site when a new product quality database was implemented. One manager had to conduct several workshops with operators and rejected incorrectly completed log sheets for several months before operators began to comply. Sometimes, operating routines are too engrained in existing employees. For instance, the only significant success that Italsteel engineers have had in implementing TQM procedures at Italsteel has been among newly-hired interns from a technical program that teaches those techniques. In each of these cases, existing procedures and employee experience have had to be modified to successfully adopt new procedures.

Experience Base An organization's experience base can have a strong influence on the transfer and adoption of new technologies. In some cases an experienced workforce can be an asset, and in other cases a liability. At Italsteel, a downturn in the steel industry required that the company downsize dramatically. The union agreement stipulated that layoffs had to begin with the most senior workers and proceed though to the more junior workers. In one swift move, Italsteel lost its most experienced workers. This has meant that sophisticated process control automation equipment had to be installed to compensate for the lack of operating experience. This lack of experience becomes a burden when operators must diagnose and solve problems, or assist in integrating new technologies into the existing technologies. Ironically, as the Italsteel engineers who worked at JSF have tried to implement quality and statistical process control procedures back at the Italian plant, they have met with resistance from all but the newest employees. This is because the older employees have operating experience--experience operating in a manner very different from that at JSF.

The U.S. Polychem partner has a similar problem with continuity of experience, in that frequently, when people demonstrate competence or skill in their work, they are promoted to a higher position in the firm and they are not in position to apply that experience where it can be best used. Polychem in Germany and Japan relies more on a seniority-based system where experienced workers are still involved with production. This ensures that experts are available to diagnose problems, and that younger, less-experienced workers are taught the nuances of the production process by knowledgeable mentors. This also means that different production approaches are used at each site. For instance, with a steady and knowledgeable workforce, the Japanese Polychem partner relies relatively more on human- and experience-based problem-solving. The American partner, on the other hand, with its less-experienced workforce has come to rely relatively more on automated production technology (the same parallel could be drawn between JSF and Italsteel, respectively). That means that the U.S. Polychem partner has very sophisticated process control technology, relative to the Japanese partner. The implications for technology transfer are interesting, however. The U.S. technology and hardware can be transferred relatively easily to Japan, whereas the Japanese experience base is much more difficult to transfer to the U.S.

Another problem posed by organizational experience to technology transfer is that there sometimes is no overlap in some areas of the experience base of the cooperating organizations. This creates a dilemma in that a solution to a problem at one site may exist at another, but the potential recipient may be unable to recognize that the solution exists. Or, the potential recipient may not have the expertise to implement that solution in its own operations. For instance, the Polychem partners hold semi-annual R&D coordination meetings to apprise partners of each other's work and to exploit synergies between research projects at each site. While it does keep them up to date on research done elsewhere, some of the researchers have commented that the meetings seldom serve as a source of new ideas because their own research and that of their colleagues are so different that they seldom find a common basis for discussion. Research projects sponsored at one site by another in Polychem may be a way of integrating the experience base, assuming that understanding of capabilities, communication, and cooperation remain at high levels. Experience that is available at one site might also be "lent" to another where it is lacking. For instance, a piece of new technology was developed in Germany, but was transferred to the American partner when its original use was made unnecessary by a change in market strategy. In this case, a temporary overlap in expertise was created when the expert involved with the development of the technology travelled with the hardware for its installation and stayed through the start-up trials. The technology was transferred successfully and is still in use today.

Power structure One final element in this discussion of architecture is the organization's power structure, and how it relates to technology. Changes in technology can prompt shifts in the relative power of groups within an organization. This can have two effects on the technology transfer process, depending on how the different groups in the organization are affected, and how much power they have to intervene in the process. First, affected groups can filter information about the potential of technologies at other sites by focussing on or "turning a blind eye" to them. This is a concern for R&D managers at Polychem who may be faced with having to sponsor product development research at another site, especially if the product is clearly out of the markets in which the other partner competes. In another case, the influence of a group at Polychem was weakened because of changes mandated by the formation of the JV. In interviews with people from this group, several were initially very cautious about their accepting partners' technologies, or were skeptical that their firm would would ultimately benefit from the partnership.

The second way that changes in the power structure of the organization can affect technology transfer is by actively intervening to facilitate or interfere with the transfer of specific technologies. One group at Polychem had been heavily involved in the unsuccessful transfer of a piece of technology some time prior to the establishment of the present JV. A similar piece of technology is being transferred again, but this time, the group has only been allowed to participate on the margins because of its previous failure. In general, Polychem groups who saw immediate payoffs from technology transfer with partners were much more enthusiastic to begin transfer at the beginning of the JV. The Japanese Polychem partner experienced a "halo effect" at the beginning because of demonstrable strengths in certain production technologies. This allowed it to gain the upper hand in some negotiations early in the JV, especially relating to determining whose technologies would be used at the different sites. Over time, the relative power positions have changed, especially as the true capabilities of each partner has become more clear. However, the relative power positions of the groups mentioned in the previous examples clearly affects what technologies were to be transferred, and by whom.

Individual incentives provide a final poignant example of power balances affecting technology transfer. Information is seen as a source of power and a way to advance in the organization by some managers and hourly employees at Italsteel, so it is often not shared with others. Managers who demonstrate the greatest knowledge, and have the highest individual performance (which may simply mean not doing as poorly as peers) receive the promotions. On the other hand, promotions in the Japanese organizations in this study are based on tenure, so the incentive to distinguish oneself is weak. In fact, the social norms that encourage employees to be a part of the group are much stronger. This means the incentive is to share information, so that the group's performance is improved. Because of such differences in the power associated with possessing information, implementing technologies which rely on the sharing of information at Italsteel or the other Western organizations is difficult and sometimes even resisted.

Organizational Adaptive Ability

Knowledge Architectures are things that can't be changed in the short term. Organizational adaptive ability refers to the things an organization can do in the short term to increase its ability to adopt new technologies. In effect, adaptive ability is a measure of an organization's ability to "push the envelope" to act outside of the boundaries of its existing architectures. Adaptive ability is separated into staffing flexibility and production flexibility

Staffing Flexibility An organization that has staffing in excess of that required for normal operations can easily re-deploy people to work on technology transfer and implementation. However, firms seldom have excess people waiting to be re-assigned. In fact, staffing pressures were cited repeatedly by managers as a hinderance to technology transfer. Engineers at Italsteel complained that they were too busy to act as technology transfer agents once they returned from JSF because of the demands of their daily responsibilities. Two problems were cited. First, they had no time to train other people in the behaviors they had learned at JSF because of pressures to keep the existing production system up and running. Second, they didn't have any extra people to train even if they did have the time. One German Polychem manager made similar comments, and added that because of shortages of personnel in his organization, he could not even afford to transfer any people to other sites so they could learn about different technologies. One solution that is being tried at Italsteel assigns recently-hired interns to managers for training. Those assigned to the managers who worked at JSF are being trained in the JSF statistical process control and Total Quality techniques.

People that are available can sometimes be used more effectively through job re-design. In the short run, effort can be focused on certain areas of production by shifting people from other areas temporarily. This is possible only if workers are cross-trained in multiple skills. Polychem in Japan uses about the same number of people working at their facilities, but line workers are able to move from line to line and position to position so that effort can be concentrated at critical moments (for instance, when a production line is being started, it is helpful to temporarily have more workers on hand than are needed for routine operations). This flexibility saves production time that can be used for technology implementation. Furthermore, since the Japanese Polychem operators are relatively skilled they are able to assume some of the responsibilities that might otherwise be assigned to a production engineer. Finally, the fact that the operations there are relatively smooth-running means that less effort has to be spent on routine problem-solving and that more effort can be devoted to technology implementation or transfer.

Longer-term deployments of people and expertise to specific areas can increase the likelihood that technologies will be transferred there successfully. For instance, if the most technology transfer occurs in process technology areas, then expertise should be massed there if possible. For instance, the Japanese Polychem partner has about the same number of engineers working in its operations as do the German or American partners. But of those engineers, a larger proportion are process engineers. The engineers not assigned to the production are assigned to R&D groups where they are engaged in product development. That menas that more engineers are available at the Japanese site for process technology improvement. Because relatively fewer engineers are assigned to production in Germany, the production group sometimes has to make formal requests of the R&D group to get problem-solving help. Associated with this process are delays and potential conflicts in research priorities. However, in the process of transferring technology from Japan to Germany for a new production line, the German partner has created a production engineering group structure more closely resembling that in Japan, to try to make better use of the people it already has.

Production Flexibility Production flexibility is related to the relative availability of production time that can be used for engineering problem-solving, equipment modifications, or product trial runs. A plant that must operate at full capacity obviously cannot shut down for such activities. However, no firm in a competitive industry can build excess capacity just for the luxury of having production flexibility, either. One way to make the most of the available production capacity is to schedule several activities in parallel. For instance, all the Polychem partners spend about the same amount of time overall for production line maintenance. But of that time, the German and American partners experience relatively more unscheduled down-time than does the Japanese partner. The Japanese partner plans more scheduled maintenance time so that the time can be used for extensive equipment work and problem-solving. That time is made even more productive because with the advance planning, contractor personnel can be called in. During this period, many times the number of people normally required to run and maintain a production line can concentrate their efforts on the line. Ironically, the Japanese partner gains this flexibility by adhering to a meticulous production (based on projected customer demand) and maintenance (based on available time) schedule planned long in advance. The downside of this particular approach is that it usually carries more inventory, has slower inventory turns, and has more obsolete inventory at the end of the year than its partners. The upside, however, is a higher-performing production line and more resources available for implementing process innovation.

One way of alleviating the problem of binding production demands is by using pilot or non-production lines for experimentation with process improvements and implementation. Each of the facilities involved in the study have pilot production lines of various capabilities. One Italsteel manager saved an obsolete facility from being scrapped so that he could use it for technology and product development. This facility was used to test and prove a piece of technology that was transferred from the JSF plant. Because a test facility existed in Italy, Italsteel was able to transfer the technology from Japan with drawings, telephone calls, and faxes, with fabrication and testing taking place in Italy. Oddly, this is the only such test facility at the Italsteel plant. Italsteel does have a state-of-the-art pilot test facility located several hundred miles away near its central R&D facilities, but it is seldom used by engineers at the main plant, and is even sometimes idle. The Polychem partners have made extensive use of their pilot production lines to test new products from their partners, or to test hypotheses about why one technology has higher performance than another. Often a test of a partner's product can be made by shipping polymer from one site to another and providing the state conditions for the process. New parts or technologies are also tested first on the pilot lines before they are installed on regular production lines. Most of the Polychem engineers interviewed who had transferred technologies from their partners mentioned the use of the pilot production lines as part of the process.

The four categories, Transfer Scope, Transfer Method, Knowledge Architectures, and Organizational Adaptive Ability, and their contents are summarized in Table II.

Table II
Categories and Sub-categories of Technology Transfer Framework

Transfer Scope	Transfer Method	Knowledge Architectures	Organizational Adaptive Ability
General Knowledge Specific Knowledge Hardware Behaviors	Communications Personnel Transfers Roles Bridges	Hardware Procedures Experience Base Power Structure	Staffing Flexibility Production Flexibility

DISCUSSION

Observed relationships between the transfer scope, transfer method, knowledge architectures, and organizational adaptive ability are shown in Tables III through V. The articulations of the relationships are based on observations made during data collection.

Others, where no clear evidence exists yet, are based on inferences that follow from the framework.

The relationships of transfer scope with transfer method, knowledge architectures, and adaptive ability are defined in Table III. As transfer scope increases, more intensive transfer methods must be used. This is based on the observation that information is transferred relatively easily, whereas behaviors require somewhat more effort. The explanation for this is that as scope increases, the embodied knowledge becomes more extensive and complex (as in the case of behaviors). Therefore, more intensive transfer methods, which use media with greater information-carrying capacity, must be used.

Similarly, the greater the dissimilarities in knowledge architectures between organizations, the greater the transfer scope. This is based on the observation that more complex embodied knowledge, such as behaviors, often involves more than just the transfer of the behaviors themselves. Complex systems often have to be transferred in "bundles" of technologies or embodied knowledge. The explanation for this is that new technologies must adapt or be adapted to the architectures in their new setting. This is done by either the transfer of complimentary technologies from their previous setting, or by changes to the architectures at the new setting. Either effort is correctly associated with the overall effort involved, or scope of the transfer.

Finally, the greater the organization's adaptive ability, the greater the scope of technologies it is able to successfully transfer. This is based on the observation that organizations that can flexibly re-deploy resources are able to transfer complex technologies relatively quickly compared with others (the quickness of the transfer is associated here with increased ability). The explanation for this is that firms that can re-deploy resources can cope with greater demands and workloads in engineering problem-solving, and get more done in a given transfer effort.

Table III
Relationships Between Transfer Scope and Other Categories

	Transfer Scope
Transfer Method	The greater the scope of the knowledge transferred, the more intensive the transfer methods that are required for technology transfer.
Knowledge Architectures	The greater the difference in knowledge architectures between organizations, the greater the scope required for the transfer of technology.
Organizational Adaptive Ability	The greater the organization's adaptive ability, the greater the scope of technologies it is able to transfer.

The relationships between transfer method and transfer scope, knowledge architectures, and organizational adaptive ability are shown in Table IV. The greater the difference in the knowledge architectures between two organizations, the more intensive the transfer methods that are required. This is based on the observation that transfers between organizations with significantly different architectures usually involve a great deal of effort. The explanation for this is that architectures in an organization act as filters and channels for information. A technology that is transferred into a new setting will require adaptation, and adaptation of a technology requires an understanding of its interaction with different organizational systems. Information embodied in architectures from a different organization will be more difficult to extract, and therefore will require greater effort (more intensive transfer methods).

The greater an organization's adaptive ability, the more intensive the transfer methods it is able to employ. The explanation for this is that more intensive transfer methods require problem-solving resources that a lean production organization might not normally have. Firms that can flexibly re-deploy its knowledge assets can temporarily make resources available which can then be applied to more intensive problem-solving efforts.

Table IV
Relationships Between Transfer Method and Other Categories

	Transfer Method
Transfer Scope	See Table III.
Knowledge Architectures	The greater the difference in knowledge architectures between organizations, the more intensive the transfer methods that will be required for technology transfer.
Organizational Adaptive Ability	The greater an organization's adaptive ability, the more intensive the transfer methods it is able to employ in technology transfer.

Finally, the relationships between knowledge architectures and transfer scope, transfer method, and organizational adaptive ability are shown in Table V. It is suggested that there is no relationship between knowledge architectures and organizational adaptive ability. This is more definitive than descriptive. Recall that architectures were defined as stocks or inventories of embodied knowledge in the organization, while adaptive ability was defined as the ability to re-deploy those stocks for problem-solving. There are actually two ways to think about this issue. The first says that an organization that has a lot of experience in one area (an extensive embodied knowledge architecture) can take advantage of that experience to make frequent incremental changes to its architectures. The other line of thought is that organizations with a lot of experience in one area (an extensive embodied knowledge architecture) have excessive inertia in that area and cannot change. Since both examples have been seen in our observations, we suggest that adaptive ability should not be related to knowledge architectures, but rather is a separate quality.

Table V
Relationships Between Knowledge Architectures and Adaptive Ability

	Knowledge Architectures
Transfer Scope	See Table III.
Transfer Method	See Table IV.
Organizational Adaptive Ability	As defined here, the two are independent.

Based on the observed relationships and framework discussed above, we suggest the following implications for organizations involved in technology transfer:

1) Hardware is relatively easy to transfer, compared with organizational structure, procedures, and operating philosophy. It has been observed that transfers of hardware generally proceed quickly, while transfers of behaviors take much longer. This is a reflection of the positive relationship between transfer scope and transfer method.

2) Investment in developing architectures similar to a partner's helps the transfer process in the long run. This was observed as one firm which had previously instituted employee training programs and work re-designs proceeded with transfer efforts more quickly than one which was just beginning to do so. This preparation reduced the scope of technologies that had to be transferred from the partner. This is a reflection of the positive relationship between transfer scope and knowledge architectures.

3) Technology transfer proceeds in stages. It is observed that it begins with information, then hardware, and finally organizational adaptations. Some of the steps might be skipped, depending on the degree of similarity between firms, and the extent to which firms want to develop similar capabilities. This is a reflection of the positive relationship between transfer scope and knowledge architectures.

4) Language differences can be a barrier to knowledge transfer in international partnerships. This problem can be overcome by establishing common communication protocols and making simplicity the standard for all interactions. This is a reflection of the positive relationship between transfer scope and transfer method.

SUMMARY

An organizational capabilities-based framework of a technology transfer has been proposed. It first depicts the organization as groups of embodied knowledge which include technology, procedures, organizational structure, and hierarchical relationships. By conceptualizing the organization this way, it can be seen that different organizations rely on different combinations of embodied knowledge types to accomplish the same ends.

Next, technology transfer was then depicted as the transfer of these embodied knowledge forms between organizations. The extent of the information embodied in the technology being transferred was captured by a concept called transfer scope. The greater the scope, the more knowledge that is transferred. The approaches used to transfer the technology are described in a category called the transfer method. Transfer methods range from relatively easy to very intensive (in terms of organizational resources required) approaches. In general, it was suggested that the greater the scope of the transfer, the more intensive the methods that would be required.

Because an organization is a collection of embodied knowledge types, and the combination of types employed varies from organization to organization, a technology transferred into a new environment may have a very different connection with the rest of the organization than it had previously. The relationships between the different forms of embodied knowledge in the organization are captured in a concept called knowledge architectures. The greater the difference in knowledge architectures between organizations, the greater the difficulty of transferring technologies between them. Knowledge architectures are assumed to be static in the short term, but changeable in the long term. An organization's ability to change its architectures was defined by its adaptive ability.

Technology transfer then requires adapting new technologies to the existing embodied knowledge structure of the organization. This means accurately recognizing the scope of the transfer required to successfully implement the technology in its new environment, and selecting an appropriate transfer method. With finite resources, an organization may have to develop imaginative ways of leverage its existing knowledge architectures and its adaptive ability if the scope of the transfer is too great. For instance, using adaptive abilities to temporarily enhance the firm's architectural assets in a particular area might facilitate technology transfer there.

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