Coordination of technological knowledge flows in firms

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Abstract One of the major challenges inside firms is how to effectively manage their knowledge assets in the context of managing the transfer of technological knowledge across the firm's organizational boundaries. This paper explores technological knowledge flows and the coordination of knowledge activity through use of geographically dispersed cross-functional teams, as a way of integrating diverse knowledge via technology transfer projects. As multinational companies (MNCs) have increased the volume of technological knowledge that flows between their corporate headquarters and subsidiary operations, with rapid speed in many cases, many large firms are having to face increasing challenges of now transferring more 'softer' forms of technological knowledge, since this is recognized as an enabler of competitive advantage for firms. Developing this theme, the paper provides a theoretical review of some helpful contributions in this area and provides some empirical research knowledge management insights, gained from conducting research interviews with different functional managers from four UK-based multinational firms.

Keywords Knowledge management, Team learning

Introduction

There has been a growing realization that successful technology flows in relation to supporting technology transfer and sustaining a firm's competitive advantage depends on the way in which knowledge is generated, articulated and shared within the organization. Many technology-based firms have responded to globalization by decentralizing geographically, either by investing in a new plant abroad or by global acquisitions. The technological capabilities of the new or formerly independent businesses need to be better co-coordinated, even where different businesses mostly serve different national markets. The modern multinational corporation poses new problems of knowledge transfer requiring co-operation between many diverse groups, including for example, R&D, manufacturing, marketing, procurement, contracts, spare parts and services etc. The problem can be particularly acute where technology is concerned, both because the technology itself can be difficult to transfer and because of the difference in culture between, say, those working in an R&D environment and those working in a manufacturing or marketing environment (Malik, 2001).

A key element in analyzing how technology is transferred internally within the firm is to consider the wider issue of knowledge and information flows. Technology can be transferred in terms of tangible assets, such as new products, plant and equipment, and in intangible form through formal mechanisms, such as patents and licences, and informally through information flows and
knowledge sharing (Menzler-Hokkanen, 1995). A more recent form of organizational innovation in multinational firms is where senior managers, planning intra-firm technology transfer activities, have employed different organizational designs to facilitate the exchange and combination of knowledge in the development of a technology transfer process. One such design mechanism is the use of cross-functional teams, which tend to be typically a project group with members not only drawn from the technology sending and technology receiving organization, but also from more than one functional area such as engineering, manufacturing and marketing (Brown and Eisenhardt, 1995). We believe that it is more helpful to articulate about technology as knowledge rather than as artifact or process and to consider the scope of technology more widely as having organizational and social attributes. Therefore in line with Seaton and Corday-Hayes (1993), we agree that a wider view of technology transfer should be taken. This means that technology transfer is a process of promoting technical innovation through the transfer of ideas, knowledge, devices and artifacts from leading edge companies, R&D organizations and academic research to more general and effective application in industry and commerce.

This paper uses the experience of the following multinational companies, which have had and most still have prominent business and manufacturing operations based in the UK: BICC Cables; Corning; ICI; and Pilkington. Some important empirical research findings are briefly presented here from a number of the most common themes arising from interviews conducted with managers from different functional disciplines in all four firms. By common themes, we mean the most commonly cited issues in the context of managing technological knowledge flows across multinational company geographical and organizational boundaries, as cited by managers at these four companies. This evidence has been gathered from ongoing programs of empirical research in the areas of technology management and knowledge management conducted at PREST (University of Manchester) over the last four years.

Transfer of technological knowledge

The word “technology” is extensively used across many academic disciplines and amongst many professional institutions around the world, yet it may have a different meaning in different contexts and organizational settings. This ambiguity is caused by historical changes in the content and character of activities considered as technological (Lin and Berg, 2002). Burgelman et al. (1996, p. 2) define technology as “the theoretical and practical knowledge, skills, and artifacts that can be used to develop products and services as well as their production and delivery systems”. Penrose (1959) stresses that knowledge is an important intangible resource for the growth of the firm. Therefore, as confirmed by Lin and Berg (2002), knowledge is an important aspect of technology that is tacit in nature and difficult to transfer. It must also be pointed out that most technological knowledge is highly firm specific, tacit, personal and less transferable across organizational boundaries (Kogut, 1988). To transfer such technological knowledge, the knowledge receivers would need to usually establish a much closer and more interactive relationship with the knowledge providers (Roberts, 2000).

‘Knowledge’ plays an integral role in the firm’s business activities and is probably the most important component of technology transfer. As Lahti and Boyerlein (2000) contend, key knowledge must be able to be shared, disseminated, and used on a company-wide basis so that it becomes a potential asset. Gupta and Govindarajan (2000) have termed this type of knowledge transfer as being in a “complementary context”. This refers to the transfer of knowledge along different stages in the company’s value chain, e.g. the transfer of technical knowledge (integral to technology transfer) from the development laboratories to the factories and the marketing units and then transfer of market knowledge from the field back to the factories and laboratories. Here knowledge transfers occur in contexts where the source and the target units possess complementary knowledge stocks.

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Traditionally most firms operated under a centralized product life cycle model, where firms were presented with the issue of transferring existing technologies from the “home base” to overseas subsidiaries. Thus whilst overseas subsidiaries transferred products and processes which were already well established the parent company reserved the most advanced and profitable lines for its home market (Taylor, 1994). “The focus of such transfers were in the form of embodied technologies, such as plant and equipment, or in existing codified knowledge available in blueprints, technical drawings and manuals. These transfers were involved with moving the direct ‘results’ of innovation, rather than the delivery of a wider ‘envelope’ or mechanism which would allow understanding and learning about the innovation process itself. At this level, therefore, such transfers involve little in the way of building long-term technological competencies in overseas subsidiaries. The barriers associated with the transfers of existing technologies should not, however, be underestimated. This is because although such technologies may not have been ‘new’ to the firm as a whole they are new to that particular overseas operation to which such a technology is being transferred. Even embodied or codified technologies, which are relatively mature, involve the development of new organizational and technical skills which allows the assimilation and adaptation of imported technology” (Howells, 2000, p. 810).

The existence of a strong co-operative and collaborative culture is an important prerequisite for knowledge transfer between individuals and groups. Without appropriate mechanisms to encourage co-operation, structured or technological interventions to facilitate knowledge transfer may not work. “Establishing a collaborative and co-operative climate in an organization will not alone improve knowledge transfer. There is also a need to foster a culture of problem seeking and problem solving. An experimenting and innovative culture encourages employees to look for problems as a way to improve the organization. Failures in experimentation should be expected and tolerated, and treated as learning lessons by employees and the organization” (Goh, 2002, p. 26).

Much of the theoretical literature on technology transfer by firms has centered on a manufacturing focus and on “hard” technology associated with artifacts. By contrast “softer” technologies and more tacit forms of knowledge activities associated with technology transfer have remained neglected, despite their importance and the growth in technology and knowledge-based service activities (for example, see Grosse, 1996). By neglecting the softer technologies and service sector element of technology transfer, we may miss important aspects of the international technology transfer process. We also ignore the wider range of knowledge-based activities associated with this type of transfer arrangements, such as marketing, maintenance and servicing, which are often crucial in the innovative performance of technology based firms (Howells, 2000).

The “bundling” of products, services and systems can potentially enhance customer value. Manufacturing has become less profitable in many of the advanced economies around the world and many manufacturing firms have begun to shift into “service delivery”. The product concept associated with the era of mass production is based on providing distinctive goods and only meeting the partial solutions to respond to customers’ needs. The next generation of manufacturing enterprises will have product concepts based on offering individual customers, total solutions tailored to their exact needs, which will require more collaborative efforts in multinational companies and probably an increase in technology transfer programs. Also it must be noted that these solutions would have to be configured and reconfigured instantaneously to meet customer requirements that could, in theory, change on short time scales of the order of minutes.

**Cross-functional teams**

In spite of the apparent advantages of designing teams for knowledge diversity, it is not that clear how team members make effective use of this knowledge. Some empirical research evidence has suggested that knowledge diversity may be both very good and occasionally a
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burden. Dougherty (1992) has shown that cross-functional teams performed better when they combine their perspectives in a highly interactive and iterative way.

Assembling the ideal functionally representative team requires some degree of dispersion of its members, because commercial offices are often physically separated from manufacturing sites, and sales representatives are regularly on travel visiting clients. In addition, as industrial competence has become increasingly geographically dispersed, specialized knowledge is sought not only from different functions and occupational backgrounds but also, by design, from members in different cultural localities (Leonard et al., 1998). Also the use of cross-functional teams in technology transfer arrangements supported by information and communication technologies, is a way of responding to the dispersion of essential employees in downsized and lean organizations and of facilitating access to key expertise (Townsend et al., 1998).

Cross-functional group composition increases the amount and variety of information available to the development project members, who are situated in different parts of a multi-divisional firm, enabling discovery and evaluation of different design alternatives from a number of perspectives (Brown and Eisenhardt, 1995). Such teams are employed to respond quickly, creatively, and flexibly to problems, which can be seen as capabilities considered critical in highly complex and uncertain environments. Here it must also be acknowledged that cross-functional teams are increasingly operating as “virtual teams” in technology transfer projects. The virtual team can be described as a co-operation between several autonomous partners who work towards a common goal. Due to a high degree of decentralization in globally dispersed virtual teams, communication and coordination is primarily based on modern information and communication technologies such as the Internet, shared databases, groupware, as well as conventional telephone and fax modes. One of the potential barriers to knowledge sharing in virtual teams might be “language barriers”. This can be business versus technical aspects (especially within cross-functional teams), and cultural barriers. One traditional drawback of virtual teams engaged in international technology transfer in the past, has been the limited amount of “tacit knowledge” transfer, which might inhibit satisfactory progress of the project as a whole. However, future communication technologies are expected to help increase the volume of tacit knowledge flow. For example, advances in microelectronics, Internet information throughput (bandwidth) and data transmission should all help to reduce the need for time-consuming long distance travel meetings even further.

A project leader usually heads most cross-functional teams employed in technology transfer projects in large firms. As Brier et al. (1996) points out, project leaders need to earn the positive support of their colleagues throughout an organization by building credits early on, in order to stand them in good stead later. Therefore a project manager for technology transfer projects needs to show: an appreciation and understanding of technical issues and difficulties that might be faced; an understanding of the financial costs, benefits and risks to which his project exposes the organization to; a range of management skills that gain widespread commitment and satisfaction, whilst minimizing negative and de-motivating consequences. Furthermore, project managers and senior managers must be good listeners and openly accept ideas generated by overseas subsidiaries, which might ultimately impact on the wider MNC. Hence familiarity with the political network of the MNC can highlight aspects that are important in the wider company context.

Knowledge management experiences of companies

Introducing the firms

Empirical data was collected from the four firms from two programs of research into technology management and knowledge management related activities over the last four years, where part
of the main topics discussed concerned the management of technological knowledge flows across organizational and geographical boundaries. Other firms were also interviewed in connection with these studies and wider management themes, where findings on other themes have been reported elsewhere. Data was gathered from conducting over 30 semi-structured interviews with a cross-section of senior managers and project management staff from BICC Cables, Corning, ICI and Pilkington. Interviews typically lasted between one and two hours and were later transcribed. Interview questions were designed to elicit information about the nature and coordination of technological knowledge transfer activities and the nature and origin of knowledge drawn upon during these activities, and how, why and with whom particular knowledge intensive interactions and technology transfer agreements took place.

BICC Cables was a leading UK based cable manufacturing company with international subsidiaries based in Europe, Asia, Africa and North America, employing about 10,000 people worldwide. However, by the late-1990s profits from the cables sector fell sharply and other factors resulted in a poor performance. These factors included a steep fall in optical fiber prices worldwide, fall in demand for energy cables, overcapacity in the European cable markets and lack of investment opportunities in the Asian markets. Therefore BICC plc decided to completely withdraw from the cables business and divested all their cable companies by 1999.

Corning has developed leading positions in the telecommunications, information display and advanced materials industries. They are a leading manufacturer of optical fiber, cable systems and photonic technologies for the telecommunications industry; and high-performance flat glass for television and information display applications. With research centers around the world and more than 70 manufacturing locations, the Corning group consists of approximately 22,000 employees worldwide.

The ICI Group is an international business employing 36,700 people worldwide. Their product range is 50,000 strong and in 2002 total sales reached £6.1 billion. The ICI Group comprises the International Businesses of National Starch and Chemical Company, Quest International, Uniqema, and ICI Paints, as well as the Regional & Industrial Group, made up of businesses which are more regional in their scope with principal locations in India, Pakistan, and Argentina. A Technology Board, including the senior business research and development managers and led by the Senior Vice President for R&D, is responsible for the development of the Group’s technology strategy and its implementation by ICI’s businesses.

Pilkington is one of the world’s largest manufacturers of glass and glazing products for building, automotive and related technical markets. The Group has annual revenues of £2.8 billion, manufacturing operations in 24 countries on five continents and sales in 130 countries, employing around 25,600 people worldwide. The technology function has been developed to meet the needs of the building and automotive products business lines, ensuring that each has access to its unique technologies as well as those (such as glass composition and coating) which are common to both. Each business line operates a globally managed R&D program and there are strong links between the two.

All findings from these companies are reported in an anonymous fashion and not directly attributed to an individual company for confidentiality protection. The firms will be referred to as “Company W”, “Company X”, “Company Y” and “Company Z”.

Main company wide findings

Company “W” offers an example of a company in a key innovative sector, which invests in a large scale R&D activity both internally and through well-developed external networks. This interactive process of knowledge transfer involves specifying and translating internal needs of different company functions and transferring back of feedback information into the technology transfer process, which is seen as a complex process of knowledge interaction and decision making in Company “W”. Because different teams in Company “W” encompass diverse expertise and knowledge, some team members often engage in widely varying tasks and were concerned with different priorities and issues. For example, members with commercial ties were strongly tuned to the interests of individual customers. Those from manufacturing were primarily concerned with capacity constraints in various facilities, production targets, and
demands that any new technology transfer type projects might place on the chosen production facility. Thus, teams have to find ways to agree upon the implications of certain findings and conclusions, despite differing priorities and occupational knowledge bases.

In Company "Y" it was confirmed that the use of cross-functional groups in technology transfer arrangements has consistently been linked to innovation process performance (see also Clark and Fujimoto, 1991; Brown and Eisenhardt, 1995). Using team members from different intellectual and occupational backgrounds increases the likelihood of combining knowledge in novel or creative ways, by bringing diverse skills, abilities, and knowledge and cognitive styles jointly to bear on the issue. Cross-functional team compositions increase the amount and variety of information available to the technology transfer project members, enabling discovery and evaluation of different design/development and manufacturing systems alternatives from a number of perspectives, according to staff interviewed both at Company "Y" and Company "W". These types of teams are employed to respond quickly, creatively, and flexibly to problems, which can be considered as critical knowledge assets that are vital in highly complex, uncertain, or especially non-routine type environments.

From the experiences of all companies interviewed here, it appeared that dispersed cross-functional teams must actively integrate the knowledge obtained through boundary spanning, to allow shared understanding of technology transfer project objectives and status. For most of these teams this presents a number of hurdles and significant challenges that must be overcome. The process of integrating knowledge from different perspectives and discoveries demanded a conscious effort and ongoing attention to detail. In particular, site specific knowledge can easily be taken for granted. Thus, dispersed cross functional teams need to learn a different way of interacting and communicating than might be adopted naturally if they were physically colocated, since most of these teams are located in different multinational company subsidiary units around the world. Discovering and developing procedural norms for interacting effectively in a dispersed team may be as important as learning related to the technical aspects of technology transfer programs in large firms.

Often differences between the sender of a technology package and the receiver will impose barriers to the effectiveness of communications and thus the knowledge transfer success. According to staff interviewed at Company "X", barriers affecting knowledge transfer success can include organizational and technological competence gaps. Sometimes information that the technology sending organization intends to send out may be misinterpreted by the technology receiver because of national and organizational cultural differences (also confirmed in Malik, 2002). Furthermore in Company "X", as also confirmed in a study by Lin and Berg (2002), some standardized operational procedures associated with technology are rooted in the sending organization's organizational culture that may be difficult for the receiving organization to duplicate in a short period of time. The technology may not fit well into the receiving organization if there are significant competence gaps between the sender and the receiver, as the receiver could have difficulties in learning and understanding the true essence of the technology.

As many of the simpler scientific and technical discoveries have now been made, Companies "W" and "Y" mentioned that they have to increasingly deal with much more difficult and intractable scientific problems. Therefore products are becoming more sophisticated catering for these new more complex problems and consumer demands, which means there is an increasing reliance on coordinating knowledge transfer between different parts of these companies. The number of technologies per product (TPP) is therefore increasing in many consumer and business products. An often cited example of this is the shift from mechanical to electro-mechanical systems in the automobile industry (Miller, 1994).

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Companies “Y” and “Z” specifically mentioned that they are both seeking to “do more with less”, maximizing the returns to their technology transfer activities, identifying core capabilities and even outsourcing some capabilities that are deemed to be “non-core”. Thus, in the flat glass sector, Company “Z” has long contracted-out R&D work, engaged in university-based collaborations and used licensing of technology routes and so forth. Nevertheless, the issue of technological knowledge transfer has become more acute for the company as it consolidates on its core technologies and makes more and more decisions about transferring more technologies and knowledge between its international organizational boundaries. Equally in the chemicals industry, the issue of technological knowledge transfer is particularly pertinent to Company “Y” in the light of its acquisition of a specialty chemicals business and the subsequent need to develop an integrated technological capability across the new group of companies, which includes recent acquisitions. Thus, Company “Y” faces a situation where its acquisition of the specialty chemicals business and the disposal of some of its other businesses has moved the company into a very different technological and business fields and is requiring a radical reappraisal of Company “Y”’s established norms and values as well as its organizational procedures.

As mentioned by Howells (2000), in addition to the shift from transferring “hard” and more formal technologies towards “softer” and tacit forms, has been a move away from the more centralized and hierarchical organizational structures of multinational companies towards more decentralized pattern of relationships. Companies “X” and “Z” mentioned that although technology flows have never been simply one-way, forward vertical flows from the domestic base to overseas periphery (with reverse flows being in evidence) have become more horizontal, two-way flows between all the firms’ domestic and subsidiary operations. Companies “X” and “Z” have sought to implement these structures to allow more autonomy and flexibility throughout their organization, and more generally horizontal structures of information have become more efficient than vertical ones, according to these two companies.

Implications and conclusions

Organizational, cultural and informal factors can also influence the management of technological knowledge flows inside firms. For a number of companies, the trend towards the decentralization of much technological activity and the removal or downsizing of central R&D laboratories has presented important challenges. In three of the companies interviewed, this has particularly raised issues about the role of the corporate center in facilitating the transfer of technological knowledge between strategic business units. A number of the companies told us of decisions to transfer knowledge within their firm boundaries that had been taken by managers with responsibility for a particular technology transfer project that had subsequently proved to have major implications for the technological direction of the company as a whole.

The familiarity of the business unit technology transfer project partner, the size of the technology transfer project and the number of other partners involved, and how new the type of technological knowledge being transferred is, all affect the nature of this type of collaborative process in most firms. Some of these factors are in turn associated with others, thus familiarity with another business unit partner may be linked in with trust and risk reduction, whilst newness of the knowledge being transferred may be associated with levels of uncertainty, but also as mentioned by Senker (1995), alternative in-house availability of knowledge. In one way, therefore, subsidiary operations now have an improved capacity to receive and utilize knowledge transfers from their corporate center and the rest of the firm, so it could be argued that the individual international technology transfer process within the large firm has become easier. On the other hand, the collective situation of intra-firm knowledge transfer has become much more complex and fragmented, and hence difficult to manage and organize (Howells, 2000).

One implication of the empirical based findings presented in this paper is that dispersed cross-functional teams provide a very interesting mechanism for promoting organizational learning. This is not only because these teams are a vehicle for developing new, innovative products and technological process solutions through which the firm can better respond to emerging market needs, but also because they can give rise to residual gains in the form of knowledge dispersion
in the firm as a whole. Specifically, in the process of solving problems for a specific technology transfer project, team members learned "who knew what, where" and contributed to diffusion of this knowledge more broadly within the firm. Thus, following Huber's (1991) definition of organizational learning as diffusion of information within an organization, these teams were clearly agents of company learning.

Developing a high level of trust is a prerequisite for developing a collaborative culture. As mentioned by Goh (2002), organisations need to be aware of the type of knowledge to be transferred and the need to recognize that certain characteristics of the knowledge source and the recipient can influence the success of the knowledge transfer. Less structured knowledge sharing processes like mentoring, personal intranets, group dialogue and post project review sessions are all helpful building blocks for the development of more formalized knowledge sharing arrangements, such as technology transfer programs in firms.

It is important to acknowledge here that it is as important to identify technologies and markets through the exploitation of knowledge transfer inside firms, not just to move into and satisfy these technologies and markets, but also to help the firm to select those to enter and develop. If the "knowledge base" of the firm can be narrowly defined as the specific technologies and markets of which it has experience (Metcalfe and de Liso, 1996), then the focus here is on the firm positioning itself in relation to what it wants as its future knowledge base.

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