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Networking For Global New Product Innovation

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ABSTRACT

The competitive advantage of companies that successfully develop new products globally lies in their ability to effectively manage knowledge across national boundaries. When it comes to global innovation, it is the dynamic creation, accessing and transfer of knowledge –explicit and tacit—that makes the difference between success and failure. Yet, we have a limited understanding of how global firms create, access, and transfer knowledge that is scattered worldwide to innovate in their product development process. Based on the findings from our two year investigation of the global product development effort of an international organization, we suggest how social networks are used to manage complex interdependencies and create social capital that is leveraged to access knowledge critical to global innovation.

NETWORKING FOR GLOBAL NEW PRODUCT INNOVATION

INTRODUCTION

The successful design and implementation of a process that allows the creation, access and transfer of knowledge for global new product innovation is not well understood, yet the importance of such a process is well established (Cohen and Levinthal, 1990; Nonaka and Takeuchi, 1995; Subramaniam and Venkatraman, 1997; Leonard and Sensiper, 1998). There is general agreement that new product innovation is an important source of competitive advantage for companies (Leonard and Sensiper, 1998). But, managing new product innovation has never been more complex. Not only have firms become more and more widely dispersed around the globe, but so too have the resources and knowledge these companies need to succeed in new product innovation. Knowledge is perhaps the most critical resource required to successfully execute the new product innovation process globally. Companies are faced with the challenge to create, access, transfer and integrate knowledge that exists in the firm's globally dispersed business entities as well as in the organizations with which these firms collaborate or compete including suppliers, customers, universities, research institutes, and rivals. As needed knowledge becomes ever more widely scattered in individuals and organizations across the globe, it has become increasingly difficult for companies to tap into that knowledge and effectively employ it to develop global new products.

We propose that successful new product innovation for the global marketplace depends on people's ability to create, nurture and leverage their formal and informal networks to generate social capital to tap into knowledge that is necessary to achieve innovation goals. Such knowledge may be located in any part of the organization or its environment around the world. Thus, we sought to understand how interpersonal networks evolve throughout the development of a radical innovation – a supercomputer (McDonough, Spital and Athanassiou, 2004). We also sought to understand how the complexity of knowledge flows and the interdependence among collaborating entities engaged in the global innovation process—internal and external to the firm - is related to the formation of social capital.

The first section of this paper discusses the theoretical underpinning and develops the broad research questions that guided this field study. In the second section we discuss the research methods used to guide the data collection and their analysis. The third section develops the in-depth case study of Compaq's supercomputing product development effort that leads to conclusions about the role of networks and social capital in the eventual market success of this radical innovation.

THEORETICAL FRAMEWORK

Radical innovations offer significant performance features, dramatic reductions in cost, or create new lines of business based on new ideas or technologies (Leifer, et al., 2000). The need for firms to invest in new technologies and develop radical innovations is well-recognized (Tushman and Nadler 1986). However, such innovations are often developed within the context of great market and technological uncertainty resulting in high costs, high risks, and long development times (Abernathy and Clark 1985; Utterback 1994). To reduce the multiple uncertainties associated with radical innovations, a high degree of collaboration is required among a firm's highly diverse functions. Achieving integration among these functions can be challenging given their diverse, and often conflicting, goals, time horizons, and perspectives.

Innovating globally refers to the development of new products for multiple country markets involving expertise scattered throughout the world. Developing such products creates three demands. First, it requires comprehension of the needs of globally dispersed customers who speak different languages and possess different values and beliefs. Second, it frequently involves managing physically dispersed NPD personnel who are located across the globe, have different cultural backgrounds, and speak different languages (McDonough, Kahn and Barczak, 2001). Third, it creates a need for close collaboration among individuals who are associated with the development and commercialization of the global new product, including project team members, new product managers, customers, vendors, and the like. These three demands make managing the flow of the knowledge needed to develop radical innovations for global markets an extremely difficult and complex undertaking (Leonard and Sensiper, 1998). The reason stems from the greater equivocality and ambiguity inherent in creating or acquiring the knowledge needed for such development efforts.

Equivocality and Ambiguity

Equivocality refers to multiple meanings for or interpretations of the same thing that can be given by multiple managers (Zack, 2001, Daft and Macintosh 1981, Machlup 1980, Weick 1969), while ambiguity represents a difficulty in interpreting or making sense of something (Machlup 1980, MacKay 1969, Weick 1969).

Equivocality created by developing products suited to multiple national markets by globally dispersed personnel is likely to be greater than when developing a product for a single national market by individuals within that country. This higher level of equivocality results from the team members' and managers less developed understanding of each of the country markets as well as the physical distance of personnel from the source of the knowledge flowing from multiple globally dispersed locations. Ambiguity for global innovation is also likely to be higher by operating in multiple countries with different cultural assumptions and different institutional environments. Under such circumstances, NPD personnel are more likely to have difficulty understanding a wider array of customer needs, choice criteria, or the uses to which a new product will be put. Equally, project teams and NPD managers are more likely to have difficulty leveraging the knowledge they have or acquiring the necessary knowledge to develop a global product that fits multiple customer needs.

The degree of equivocality and ambiguity is also likely to be higher when firms are developing radical as opposed to more incremental innovations. In radical innovation efforts, technologies are new or untested in the current applications leading to knowledge that is ambiguous and complex. Since radical innovations involve the transfer and integration of largely tacit knowledge (Leonard and Sensiper 1998), equivocality and ambiguity is likely to be high (Zack 2001).

One important means of assimilating the tacit knowledge that is needed in the development a radical, global innovation, and thus reducing equivocality and ambiguity, may be by having individuals build stocks of social capital (Putnam, 1993) with others within and beyond their firm's boundaries. And, building these stock of social capital may be best accomplished through the development of appropriate interpersonal networks.

Social Capital, Interpersonal Networks and Knowledge

Social capital is the value of the intangible resources lying in relationships among people. It can be drawn upon by those in the relationship to help them achieve something they could not otherwise do (Burt, 1992; Coleman, 1988; Lin, 1999; Nahapiet & Ghoshal, 1998). Lin (1999) suggests four elements of social capital to explain why embedded resources in social networks enhance the outcomes of actions. First, a social network facilitates the flow of useful *information*. Second, a network member's social ties wield *influence* on others in the network who play a critical role in decisions. Third, a network member's access to resources through social ties offers a certification for her/his *social credentials*, i.e., her/his credibility. Finally, a network member's access to social relations *reinforces* his/her identity and recognition in a network.

Social capital underlies patterns of value creation in the complex and ever-changing sets of relationships needed by managers of firms engaged in global innovation. Because global innovation involves the development of new products across the borders of multiple markets, social capital may be an important mechanism to identify resources in relationships among a network of persons that have as their common purpose the global innovation effort and between the members of this network and others in their environment. Thus, social capital may become an enabling mechanism for sharing intellectual capital, or knowledge (Nahapiet and Ghoshal, 1998), an important part of a global innovation network's task. Intellectual capital consists of individual and group-level knowledge (Spender, 1986). Further, this knowledge can be tacit or explicit (Polanyi, 1962). The creation of new intellectual capital in global innovation is crucial because it addresses the new product managers' need to understand its multinational activity network – its nature, and its linkages – embedded in different environments across national borders. These managers have tacit knowledge of how the innovation effort needs to be shaped by their local contexts. Thus, social capital may be a critical enabler for managers dispersed world-wide to capitalize on their relationships and create a shared understanding of the goals of the innovation effort - new intellectual capital- and of the different challenges that each of the individuals and entities involved in the development effort may face in achieving these goals. But, social capital creation depends on building strong relationships among persons who bear knowledge of the dispersed markets for which the innovation is intended. How to build these worldwide relationships is a critical task confronting these managers.

In sum, this study has three key aims. The first is to increase our understanding of the relationships between social capital and interpersonal networks in the context of the process of developing a radical, global innovation. The second is to enhance our understanding of the role that social capital and interpersonal networks play in facilitating the flow of knowledge, especially tacit knowledge in a global innovation project. The third is to provide additional insight into the means that managers can employ to facilitate the development of interpersonal networks and the building of stocks of social capital among individuals in those networks.

METHODOLOGY

To develop insight into the role of social networks and social capital in transferring knowledge in the global innovation process, we employed a grounded theory approach. A grounded theory approach is particularly well suited to aid in obtaining an in-depth understanding of how networks, the impact of contextual elements, and the role of key actors evolve over time. It is ideal for searching for underlying patterns and consistencies (Stake, 1995). This search process and the subsequent data interpretation are at the heart of qualitative research (Erickson, 1986). Thus, instead of simply reporting on what was found, the researcher's role is to interpret events and draw inferences from the data.

Data Collection and Analysis

We conducted a longitudinal case study of a new product development effort that took place globally. Specifically, we examined Compaq's high performance computing effort that was led by its Irish subsidiary (HGO). Case studies are particularly appropriate when the focus is on "how" and "why" questions (Yin, 1984). A case study is also appropriate for understanding the interacting factors that impact on the global innovation process. It is an important means of obtaining data from multiple sources of data from multiple levels and sections within the organization as well as multiple sources of data from organizations and individuals outside of the organization.

Data collection took place over a two year time span, beginning in May 2000 and concluding in May 2002. With one exception, data were gathered via face-to-face, in-depth 1.5 hour interviews by four faculty researchers. We conducted a total of 26, one, to one and one half hour semi-structured interviews with 22 individuals. Key informants were interviewed twice and the head of HGO was interviewed formally three times. We also had follow-up discussions with this individual several times to clarify points raised in the interviews. Interviews were conducted with nine individuals in Compaq's US organization, seven individuals in HGO, three individuals with a complementor company in England, and three individuals with a customer in the US (Table 1). The complementor is a company that was not just a supplier of technology to the Compaq-US organization. HGO worked very closely with the complementor to develop and integrate its technology into the new product. This was much more than a simple vendor relationship.

TABLE 1

The Interview Sample

Categories	Home Organization	HGO	Customer	Complementor
Senior Management	1	2	1	1
Engineers	3	2	2	
Departmental Personnel (non-engineers)	5	3		2
Total	9	7	3	3

Semi-structured interviews are an effective means of investigating research questions and conducting exploratory research because they allow for flexible questioning, the explanation of questions that are unclear, and probing to help respondents provide complete information (McDonough and Leifer, 1986). Due to the exploratory nature of our research work, and the inherent complexity of the topic, we believe that a semi-structured interview was the best data collection procedure for our research.

Based on accepted grounded theory methodology (Stake, 1995; Erickson, 1986; Eisenhardt, 1989; Brown and Eisenhardt, 1997; Strauss and Corbin, 1990), each interview was conducted using a protocol that specified a common set of open-ended questions. These questions stemmed from our review of the literature, interviews with three experts in the field, and interviews with senior executives in other firms engaged in global new product development. Interview questions asked about the background of HGO, roles of individuals, relationships, capabilities, methods of communicating and sharing information, and the organization culture. As the interviews proceeded, follow-on questions were asked to pursue other relevant issues that arose during the course of each interview. During the data collection process each interview was recorded with the permission of the informant and subsequently transcribed.

In addition to the interviews, we also reviewed secondary data sources, company documents, as well as public documents. These included organization charts, documents relating to each organization's new product development efforts and process, and information from the internet including each organization's web site.

Data analysis began by reconstructing the evolution of the HGO's development of products. Interview transcripts were content analyzed to identify general patterns in the data using an iterative process consisting of multiple readings of the interviews by the researchers. The goal of this process was to achieve convergence around a set of themes that emerged from the data. Not all aspects of the interview and the data that resulted from the interviews were given equal emphasis in this process (Stake, 1995).

Following our preliminary analysis and sense-making, we provided feedback at three different levels within the organization through dialogue sessions that involved many of the individuals interviewed at that location, as well as other company personnel. These interactive feedback sessions allowed us to reach a deeper understanding of the issues involved.

DISCUSSION

Background Of The New Product Development Of Compaq's Supercomputer

In 1993, several senior Compaq-U.S. managers were trying to get supercomputing started to create a market for one of their key technologies. Unfortunately, at the same time, the company started significant downsizing and consolidation. Any transparent effort that exposed the company to additional risk that required investment in a new organization, new capabilities, and the development and delivery of a new product, would almost certainly be thwarted by severe budgetary constraints. Thus, these senior managers chose to locate the supercomputing effort where it would go virtually unnoticed - in Compaq's Irish subsidiary (HGO). HGO was managed by highly qualified technologists who lacked expertise in supercomputing. However, what these technologists lacked in expertise was more than made up for in motivation. Due to declining sales, Compaq had recently transferred HGO's manufacturing function to other parts of Compaq's global organization leaving HGO with little work and dim prospects for survival.

Thus, while HGO had the support of several senior managers at the company's US operations, they had no corporate mandate to enter the target market, no business plan, no development plan or established customer contacts, and insufficient technology prowess in high performance technical computing to interest customers. Indeed, HGO's deliberate strategy was what one manager referred to as a "stealth" strategy to keep their product innovation team below the corporate "radar horizon" while it developed knowledge and competencies.

Driving their efforts was a broadly stated goal to become a significant competitor in the supercomputer market and to "do something important." As one senior engineer pointed out, "The strategy of the group was to become stronger and become a big leader in supercomputing, but the way of getting there wasn't clear." Longer term, HGO managers were interested in developing products that would generate profits for the corporation. Thus, it was necessary to understand customer needs and problems so that accumulating technological expertise could be directed toward the development of a commercially viable product.

Phases in the Supercomputer Development Process

We found that HGO's global product development effort could be separated into three, relatively distinct phases: *wandering about in the wilderness*, *heroic experimenting*, and *stable commercializing*.

[Insert Figure 1 about here]

Wandering about in the Wilderness

In the first two years of its existence, the first phase of the global innovation process, HGO did a considerable amount of "wandering about in the wilderness" looking for opportunities to make money through a supercomputing new product effort. HGO needed to develop its own technical competence in order to begin to understand the needs and problems of customers. To this end, HGO's senior manager understood that he had to build relationships that allowed him and his team access to new knowledge. To do so, he developed relationships among the members of his core engineering team and purposefully engaged the interest and expertise of selected engineers in the U.S. operations. Further, he assigned selected Ireland based engineers to work on projects of US based development teams. He also recognized the importance of developing relationships early with potential customers. Customers in this business require "benchmarking" tests before purchase so that they can evaluate the performance of products in their particular environment and for their specific task. HGO provided this service free. Through this benchmarking activity customers described their needs in ways that allowed HGO engineers to begin to understand them. In short, HGO managers sought to learn about what they didn't know.

Heroic Experimenting

After two years of "wandering about" HGO moved into a second phase in the global innovation process. This was the "heroic experimenting" phase. Compaq-US had legitimized HGO's existence by then and formally assigned it to a long-serving senior executive in the US who was tasked to oversee the Compaq's global supercomputing effort. Concurrently, a technical director, also a long-serving Compaq-US employee, was transferred to Ireland as part of the HGO team. These two executives changed HGO's direction dramatically. The new objective was to build a reputation, both among the customers and internally within the corporation. Also, to enhance credibility in the corporation, they believed it important to generate revenues. As a first step, the technical director decided to focus the team and announce its capabilities to customers by building a working machine. His goal was to demonstrate this new machine at the annual Supercomputing trade show in approximately seven months (most "trade-show" machines were empty boxes that were strictly for show). In response to this challenge, the engineers integrated Compaq's existing technologies to assemble a very high performance computer, and unveiled it at the trade show that year. This prototype high performance machine made a huge impression both in the market and internally in the Compaq organization. A number of copies were subsequently sold to customers.

Coincidentally, a lead user in supercomputing initiated discussions with Compaq to solicit a bid for the next generation supercomputer that would meet this lead user's future needs. To initiate these discussions, a director from the lead user approached a Compaq hardware manager, whom he knew. That hardware manager happened to know HGO's new technical director and asked him to meet the lead user and help develop the relationship. Lead users in the supercomputing market are customers that buy products that incorporate the very latest technological advances; they also understand that these products rarely come completely "bug" free. A vendor has to work closely with these lead users to develop and debug the machine. By working closely with these lead users, a vendor learns a great deal about how to improve its technology to meet customer needs and problems, about competitors' technologies, and about ways to improve upon existing machines. Significantly, these lead users contributed development funds to HGO to apply to the project that Compaq was not willing, or able, to invest in while HGO was still proving itself.

HGO's first lead user needed a machine with performance far superior to that developed for the trade show. The lead user's managers identified the bottleneck element in that HGO design, and introduced HGO to a vendor located in England, that we shall call WFI.[1] WFI possessed a complementary technology for a key component of the supercomputer that was far superior to Compaq's. In the Fall of 1999, by working closely with this lead user and with WFI, HGO developed and produced the fastest computer on the market. Within three years of the first delivery of this machine, HGO had sold and installed 4 of the 5 fastest machines in the world. They had also won contracts for the biggest computers in Japan, Europe, and Australia. When they secured a new contract to build the most powerful computer in the world, the technical complexity went beyond what anyone could have imagined only a few years earlier, providing a strong reputation in the supercomputing market. Meanwhile, its reputation had become even stronger within Compaq because its huge contracts for new computers had begun to generate significant revenues.

Stable Commercializing

Beginning in 2000, focus once again shifted. In this "stable commercializing" phase of HGO's innovation process, the goals evolved to include making a commercial profit by manufacturing and selling standardized products. To achieve sufficient profitability, HGO had to

[1] WFI is a disguised name.

scale the business to produce supercomputers that were manufactured in volume to a set of specifications. These machines were sold to commercial customers not interested in leading edge technologies as much as they were in machines that were dependable and ready to work reliably. In this phase, commercial supercomputer versions were manufactured in Compaq facilities in the US, Scotland and Singapore. So HGO had to modify some of their behaviors to match the business models that drove Compaq volume manufacturing and service globally. At the same time, to continue the successful innovation process, they needed to maintain the development processes that had allowed them to get to this point. Within two years, nearly one hundred machines had been sold to customers in countries as far flung as France, Japan, Australia and the US. Each of these machines was being sold by Compaq's sales team and serviced by Compaq's after sales service organization. As of the end of 2001, Compaq had acquired a dominant market share in the supercomputing market and, perhaps most importantly, had begun to contribute significantly to corporate profits. HGO's sales had increased to account for 2/3 of all servers produced by Compaq.

In sum, Compaq's development of the world's fastest Supercomputer was a radical innovation effort involving a great deal of sophisticated technological design and development, including integrating state-of-the-art technology in ways that would achieve the desired processing speeds. The initial supercomputer was also tailored to meet the specific needs of a single customer. Thus, understanding exactly the customer's problems and needs was of paramount importance. Integrating these state-of-the-art technologies in new ways and tailoring the product for a customer resulted in considerable ambiguity and equivocality. As well, there was a great deal of uncertainty about which technologies would be of use and how to integrate those technologies in ways that would result in a product that would satisfy the customer. Lastly, there was a great deal of critical product and market knowledge that was tacit, and that needed to be transferred among members of HGO, between HGO and the customer, and between HGO and the vendor.

Building Interpersonal Networks

Prior research has had a tendency to consider interpersonal networks as given contexts, rather than structures that can be deliberately designed (Lorenzoni and Lipparini, 1999). In contrast, we found that HGO's "pre-existing" interpersonal network grew throughout each phase of the development process. In Phase 1, HGO's pre-existing network expanded to include Compaq engineers in the US as HGO took on work that these engineers couldn't get done or didn't want to do. HGO's senior manager selected two Galway engineers to forge these relationships, and to act as boundary spanners between the US engineers and the HGO development team. The US engineers were an important source of learning for the HGO team members as they sought to learn about existing technologies and to accumulate knowledge of the technologies that might be of future use. The senior HGO manager recognized that having selected engineers from HGO work with US engineers, and reliably produce results, would build relationships that would be beneficial in the future. Indeed, the network that was created led to the creation of social capital that was later drawn on to achieve results in Phase 2.

In addition, HGO's network expanded in two other directions. On the one hand it expanded to include customers for whom HGO performed benchmarking. Because the interactions with these customers were contractual and limited to the transfer of specific, well-defined knowledge, relationships remained at a relatively formal and superficial level, with little social capital being built, or needed to be built. On the other hand, HGO's senior manager developed informal relationships with key senior managers in the US to help him better understand how these senior managers would judge whether he was succeeding. Because he needed their help in understanding where he might effectively develop additional relationships with other departments in Compaq US, building strong relationships and stocks of social capital was quite important. Thus, he made a point of visiting the US operations on a regular basis and, while there, spending "face" time with key individuals in each department to keep them up to date about how development was proceeding, to find out how HGO's work was affecting their work, and in general to develop a more intimate relationship with these individuals.

[Insert Figure 2 about here]

In Phase 2, the network expanded dramatically when HGO hired a technical director, and along with him, acquired his interpersonal network. Prior to joining HGO, this individual had worked at Compaq's operations in the Pacific Northwest of the US. Thus, his interpersonal network included individuals at that location, as well as individuals in Compaq's New England facility. One individual in his network in the New England operation included a hardware manager. The hardware manager's network, in turn, introduced the technical director and senior HGO manager to individuals in a government lab located on the west coast of the US. This lab turned out to be the lead customer for HGO's first supercomputer. And, it was the customer, based on its own network of relationships, that introduced HGO to a vendor, located in England, that had a complementary technology that proved critical to the development of the Supercomputer. This network, which consisted of individuals from the US, Ireland, and England, enabled Compaq to have access to knowledge that existed in different organizations and in different countries.

HGO's internal network also expanded to include formal links with headquarters (reporting relationships), and other Compaq-US departments including manufacturing and after sales service. Thus, HGO's network of relationships evolved to include a lead user, a technology vendor, formal links with headquarters (reporting relationships), and other Compaq-US departments. At the same time, they discontinued simple interactions with the initial benchmarking customers and instead worked intimately with a lead user to understand their needs and to finalize the design of the product.

[Insert Figure 3 about here]

In Phase 3, HGO's network expanded further to include individuals who served as bridges and buffers. To ensure that the needs of both types of customer were met, HGO's network bifurcated into two relatively distinct network clusters that pursued different goals and relied on different levels of social capital to manage knowledge flows and to handle the interdependence associated with each network cluster.

[Insert Figure 4 about here]

One network cluster was composed of the innovating core team, the complementary technology vendor, lead users, and a few individuals within the US. This network cluster was essentially the "original" Phase 2 network. HGO needed to maintain dense ties with high levels of social capital among network members and a strong focus on innovation in order to foster the fast, frequent exchange of knowledge among members and the greater and more complex interdependence.

The second, newer network cluster was a commercial customer service group. It was composed primarily of individuals from manufacturing, sales, and service from Compaq, and linked the commercial customers to the innovating group. To be efficient and cost effective, these network members needed to be strongly coupled with HGO and loosely coupled with commercial customers. This service group network cluster maintained a high level of social capital with the innovating group in order to be able to solve the occasional extraordinary challenge. However, they needed a looser network and use of routine processes to interface with commercial customers. The social capital, which oiled the frictions among the different actors in the innovative cluster of the network, was not required in the service group network. In the service group network, established procedures and "rules" made interactions formal and predictable to a great extent and knowledge flows were relatively simple and routine, thus minimizing the need for social capital in smoothing out occasional disruptions. For these infrequent situations the service group acted as a bridge to the innovating group and at the same time buffered the innovating group's resources from multiple routine enquiries.

In all three phases of HGO's product innovation effort, it was important to build interpersonal networks to facilitate the transfer of knowledge appropriate to the tasks of each phase. For example, one of the keys to HGO's successful development of the supercomputer was having the lead customer, based on its own established network of relationships, introduce HGO to WFI – a company with complementary technology that proved critical to the development of these fast supercomputers. (This occurred early in Phase 2.) Granovetter (1973) describes this phenomenon as the strength of weak ties. He argues that if a tie between two nodes is strong most of the valuable knowledge that each node possesses is likely to have already been shared. Thus leading to the weakness of strong ties. In contrast, nodes, i.e., individual network members, are more likely to learn something new from the weak link with a new tie. In the case of HGO, the new tie between HGO and WFI, led to the introduction of interconnect technology that was new to HGO and critically important to the success of the project.

Network Density

A key network parameter that affects knowledge transfer is density. Density is defined as the total number of links among actors in a network (Wasserman and Faust 1994). While, some researchers have suggested the value of open and loose—low density— networks (Burt, 1992; Granovetter, 1973), others have argued that social capital must be configured in dense, closed networks to provide value. Putnam's (1993) study of Italian industrial regions led him to conclude that the northern regions created more economic growth because of their close and long-standing interconnections and relationship redundancies. Further, Coleman (1990) found that social capital networks should be dense to maintain trust and influence among members of the network and, in turn, maximize the use of the network members' resources. Our results suggest support for Lin's (1999) suggestion that closed and dense networks are best for preserving or maintaining and maximizing the use of resources, while open and loose networks are better for searching for and obtaining resources. As the development of Compaq's supercomputer proceeded through different phases of searching for information and knowledge and design and development, the network characteristics also changed to reflect the needs inherent in each phase.

In Phase 1 HGO's internal network was loosely coupled and had low density. Several team members interacted primarily with individuals external to HGO. Linkages between HGO and its customers were loosely coupled (low density). Other HGO team members interacted informally with Compaq engineers in the US. Thus, in Phase 1, when the team was trying to discern what it didn't know and what knowledge it needed, the network was open and loose. This type of network served to facilitate the search process (Hansen, 1999). Because of the open and loose structure of the network, the development team encountered fewer redundant relationships in their search, thus making the search process more efficient (Burt, 1992; Granovetter, 1973.

In the later phases when the task shifted away from search to development, a dense and closed network was created. Much of the development work by the team was carried out on site at the customer and the vendor and numerous face-to-face meetings among the team, vendor and customer were held at other times. Because this network was closed, trust and influence among members of the network remained at a very high level. This, in turn, ensured the effective utilization of resources and sharing of knowledge (Coleman, 1990).

Social Capital

One of the outcomes that resulted from the building of these networks was the generation of social capital. This social capital was necessary in order for the HGO team to acquire the knowledge, tacit and explicit, that they needed to develop a competitive advantage in high performance supercomputing. But, the tacit knowledge that they needed couldn't simply be transferred directly from one individual in the network to another. Instead, the development of tacit knowledge required the intensive sharing of the experience that individuals had gained over time. As Polanyi (1966) points our, a learner must be able to take new knowledge and integrate it with previous experiences and knowledge, and this happens most effectively when the learner is immersed in a situation using as many senses as possible. Though transfer of tacit knowledge is not possible - if it were transferable it would not be tacit - a shared understanding of tacit knowledge interpreted through the transferor's and the transferee's respective tacit understanding happens when a "teacher" (broadly defined) transfers his/her meaning of explicit knowledge to a learner through intensive interactions. By working with the same knowledge in the same context, the learner can gradually understand the explicit knowledge through tacit knowledge of his or her own (Polanyi, 1966:61) and give this explicit knowledge similar meaning to that of the teacher.

Thus, assimilating tacit knowledge, as needs to occur during the process of discovering and mastering new technologies, requires developing relationships with individuals who possess the tacit knowledge. The senior manger of HGO took a number of steps to ensure that relationships were formed between the team and the vendor, the lead customer, and the US engineers. Development team members not only met face-to-face with vendors and customers, but they also spent time on site working with them on real problems. For example, HGO team members and engineers from WFI were temporarily co-located to do real work (not just simply to meet to "get to know each other better"). Senior managers from HGO and WFI also met face-to-face on a frequent basis – alternating meeting at one company or the other. In the case of the customer, two development team members spent several months at the customers' facility collaborating on the development, resolving problems, and refining the design.

HGO's relationship with the US engineers also changed considerably over time. During Phase 1, the interaction was relatively simple and learning was one-way, with the HGO engineers extracting knowledge from the US engineers. During Phase 2, the requirements of the supercomputer architecture and performance meant that HGO needed technology the US engineers did not have and could not produce within the schedule. So HGO had to develop substantial technology itself. In addition, the technology complementor's architecture required changes in the US engineers' existing technology. The interactions between HGO and the US engineers became highly interdependent and technically complex. It is clear however, that the social capital between the HGO engineers and the engineers in the US would not have developed if HGO's engineers had not been and had not been perceived as being technically capable. Thus, the technological competence that HGO developed in Phase 1 was an important prerequisite in building social capital and expanding the network in Phase Two.

Having the development team work with individuals face-to-face for an extended period of time also created in-depth relationships based on reciprocity and trust (Birkinshaw, 2003). Creating trust in a relationship is a necessary first step in building social capital (Nahapiet & Ghoshal, 1998; Burt, 1998; Adler & Kwon, 2002, Lin, 2001). This social capital was drawn upon in later stages by HGO team members to help them achieve something they could not otherwise do (Burt, 1992; Coleman, 1988; Lin, 1999; Nahapiet & Ghoshal, 1998). It was an important means for the team to identify the resources, and in particular and most importantly the intellectual capital that was embedded in the relationships among individuals in their network. In this way, social capital enabled the team to tap into the expertise of other individuals who were not part of HGO.

Because product development typically takes place over a period of many months, and often several years, it is important to sustain relationships over time. To ensure that relationships did not degrade, the senior manger of HGO replenished relationships and stocks of social capital by holding regular face-to-face meetings (at least quarterly) with engineers at the vendor and encouraged continual email and phone conversations. This allowed them to establish mutual credibility and develop a shared understanding (Maznevski & Athanassiou, 2003).

CONCLUSION

Our research suggests that networks and social capital play an important role in enabling the transfer of tacit knowledge in situations of high ambiguity such as a radical and global new product development effort. Our findings indicate that networks are not static entities, but rather evolve and expand or reconfigure over time. These networks become more open and loose - less dense – to facilitate the knowledge search process and more closed and dense to facilitate creativity and product design and development. Thus, network configuration is a function of the global new product innovation's task demands. Perhaps even more importantly, our findings suggest that networks can be deliberately expanded to include critical resources of intellectual capital knowledge. Managers can play an active role in facilitating network development and expansion by bringing in individuals who provide access to their own pre-existing networks and by deliberately placing individuals on assignment in key locations within the network.

Our findings also provide support for the notion that the effectiveness of networks is based upon the social capital that individual network members build with other members. For networks to provide value in situations of high ambiguity, they need to facilitate the flow of tacit knowledge. The facilitation process, however, is enabled only when interpersonal relationships develop based on trust and reciprocity between network members. And it is this trust and assured reciprocity that plays a critical role in building social capital. Once again, our findings suggest that managers can play a proactive role in facilitating relationship development. By co-locating individuals and having them engage in "real-work," they create a context conducive to building social capital.

Our findings also suggest social capital can serve as an important means of identifying resources, i.e., relevant knowledge, in relationships among a network of the organization's members that have a common purpose and between these network members and others in their environment. Further, our results highlight the importance of social capital creation for building strong relationships among persons who have knowledge of the organization's dispersed activities related to global new product innovation.

We conclude by acknowledging the need for future research that furthers our understanding of the process of network expansion and the role of social capital in facilitating the flow of tacit knowledge. We have conducted a single case study, which is an ideal method with which to study such a process. However, we have focused on a single setting – the development of a radical new product innovation. There is a need for additional research that employs a multiple case studies approach and that investigates these issues in other contexts.

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Figure 1: The Three Phases of the Global Innovation Process

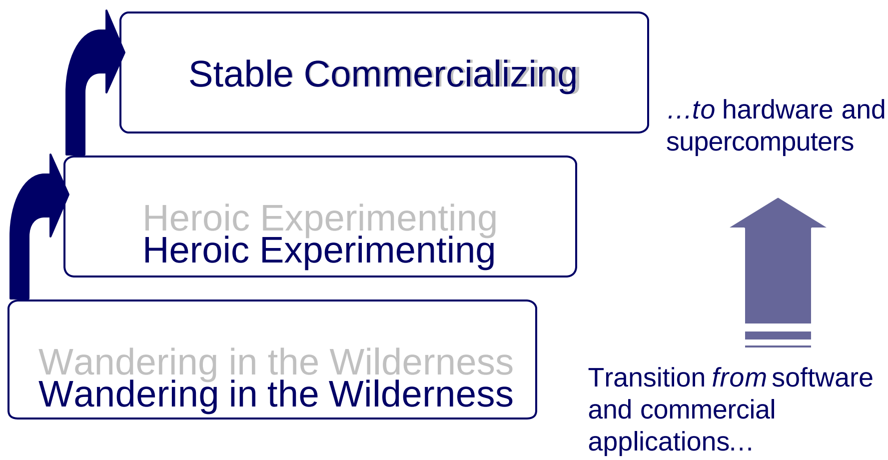

Figure 2: Phase 1 - Wandering in the Wilderness

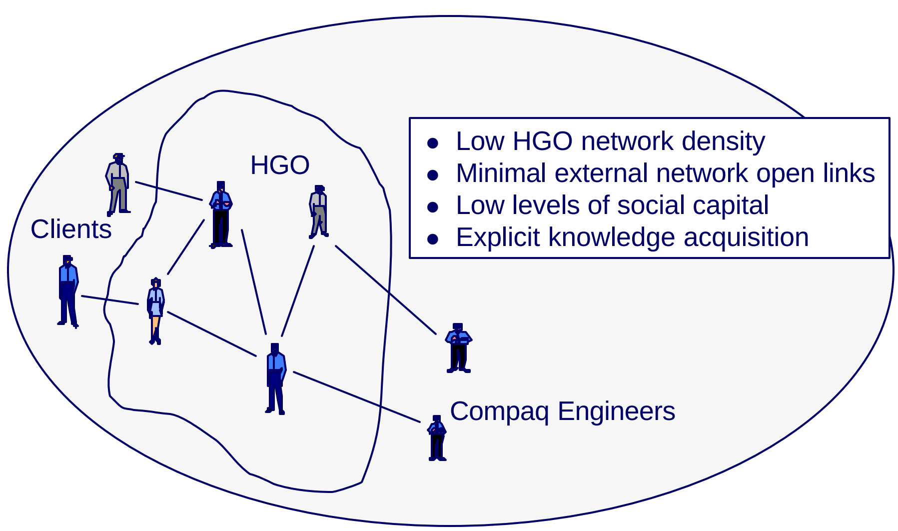

Figure 3: Phase 2 - Heroic Experimenting

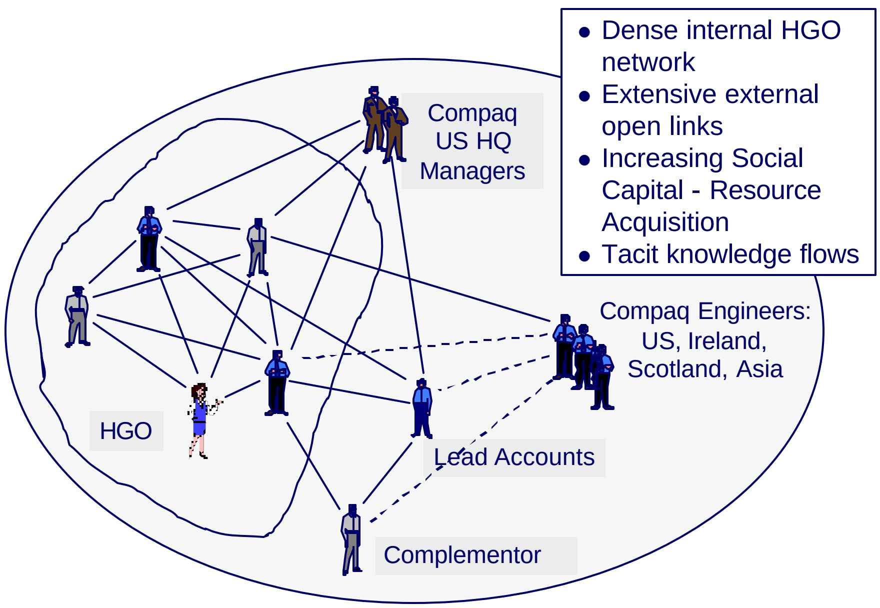

Figure 4: Phase 3 - Stable Commercializing