Institute for Global Innovation Management

Managing the Transfer of Knowledge in the Context of a Radical Product Innovation

Edward F. McDonough, III
Nicholas Athanassiou
Francis Spital

Working Paper No.: 02-006

Northeastern University
Higher Learning. Richer Experience.

MANAGING THE TRANSFER OF KNOWLEDGE IN THE CONTEXT OF A RADICAL PRODUCT INNOVATION

Edward F. McDonough III (contact author)
Northeastern University
College of Business Administration
Boston, MA 02115
(617) 373-4726
(617) 373-2491 fax
e.mcdonough@neu.edu

Nicholas Athanassiou
Northeastern University
College of Business Administration
Boston, MA 02115
(617) 373-5759
(617) 373-8628 fax
n.athanassiou@neu.edu

Francis Spital
Northeastern University
College of Business Administration
Boston, MA 02115
(617) 373-4722
(617) 373-2491 fax
f.spital@neu.edu

MANAGING THE TRANSFER OF KNOWLEDGE IN THE CONTEXT OF A RADICAL INNOVATION

ABSTRACT

Much of the prior research on knowledge transfer has focused on the transfer of knowledge from expert sites to novice sites, e.g., from one franchise store to another, and the transfer of routine knowledge, e.g., drawing standards or step by step procedures for how to process a commercial loan. In addition to routine knowledge transfer, many organizations have a critical need to find, create, and integrate highly complex and ambiguous knowledge.. Yet, current frameworks do not place their emphasis on how knowledge transfer and learning cycles work when knowledge is complex and ambiguous, nor do they examine these cycles over time. The need to understand such transfer and learning cycles is especially acute for firms that engage in new product development where tasks are inherently complex and ambiguous and the knowledge transferred is often tacit (Cummings, et al., 2003; Brockman & Morgan, 2003; Lam, 1997; Schulze & Hoegl, 2006).

This paper reports the results of a longitudinal study that investigates the knowledge transfer process in the context of a radical product innovation effort. Our results suggest that there are three identifiable phases in the knowledge transfer process and that these phases play an important role in structuring the process. Further, our research suggests that it is important for researchers to take into account three essential elements of each phase in the knowledge transfer process: 1) its key drivers, 2) its different purposes , and 3) its distinct knowledge transfer issues.

INTRODUCTION

While there is a substantial amount of research in the area of knowledge transfer, the effort has not focused on knowledge transfer as it pertains to the innovation process. The purpose of this paper is to investigate the creation, transfer and integration of knowledge across organizational boundaries. Our study focuses on the process of developing a radical product innovation in the high performance computing sector of the computer industry.

The preponderance of research on knowledge transfer has focused on the uni-directional flow or transfer of knowledge <u>from</u> the focal organization <u>to</u> a subsidiary, <u>to</u> a franchisee or <u>to</u> another part of the organization (Argote, 1999; Epple, Argote, & Devadas, 1991; Simonin, 2004; Yamin & Otto, 2004; Li & Shenkar, 2003; Lyles, von Krogh & Aadne, 2003; Lane, Salk, & Lyles, 2001; Lam 1997; Darr, Argote, & Epple, 1995; Szulanski, 1996; Bjorkman, Barner-Rasmussen & Li, 2004). The purpose of transferring knowledge in these instances is often done to "reproduce superior results observed elsewhere in the organization" (Szulanski, Cappetta, & Jensen, 2004, p. 601). It essentially focuses on the "replication of routines across geographical space" (p. 611). Thus, researchers have had a tendency to focus on the more routine aspects of the knowledge transfer process, e.g., the transfer of drawing standards or step by step procedures for how to process a commercial loan rather than the knowledge creation aspects.

Researchers often view knowledge transfer as a process with which an organization recreates and maintains a set of routines in a new setting (Szulanski, 2000) or "the process through which one (e.g., individual, group, or division) is affected by the experience of another" (Argote & Ingram, 2000: 152). Thus, with a few notable exceptions (Carlile & Rebentisch, 2003; Hansen, 1999, 2002), a great deal of prior research focuses on describing the movement of knowledge from expert sites to novice sites. Not surprisingly, this has led some researchers to suggest that "We know relatively more about knowledge retention and transfer than we know about knowledge creation in organizations" (Argote, 1999: 203).

However, for many organizations, there is a need to transfer not just routine knowledge, but also to create, transfer and integrate complex and ambiguous knowledge across the organization's internal and external boundaries. Unfortunately, as Carlile and Rebentisch point out, "current frameworks of knowledge transfer and integration do not apply with equal explanatory power to both simple and complex knowledge integration tasks" (2003: 1182), leading to the need for research that investigates the creation and integration of complex and ambiguous knowledge among internal organizational units and external partner firms.

Creating and integrating complex and ambiguous knowledge is a particularly important task within the context of innovation and new product development. Yet, with a few notable exceptions (cf. Hansen, 1999, 2002; Carlile & Rebentisch, 2003) there has been scant research that has investigated such knowledge transfer. A better understanding of knowledge transfer related to innovation is critical to organizations in an era of intensifying global competition.

In addition, little attention has been given to the flow of knowledge across interorganizational boundaries. With a few notable exceptions (cf. Carlile & Rebentisch, 2003) researchers have not focused on the reciprocal flow of knowledge between an organization and its customers, vendors, and suppliers. Their main concern has been the transfer of knowledge between partners in a joint venture or an alliance (cf. Yamin & Otto, 2004). Yet, there is evidence that, increasingly, organizations find that they need to rely on knowledge from external organizations in the process of developing a new product.

Finally, prior research on knowledge transfer assumes that it takes place in one broad learning cycle (Szulanski, 1996, 2000; Carlile & Rebentisch, 2003; Hargadon , 2003; Hargadon & Sutton, 1997; Argote, 1999; Argote & Ingram, 2000; Argote & Beckman, 1990). Some researchers, however, have suggested that smaller learning cycles are embedded within this larger innovation process. Leonard & Sensiper (1998), e.g., describe the process of innovation as being "a rhythm of search and selection, exploration and synthesis, cycles of divergent thinking followed by convergence. The innovation pattern thus occurs as fractals, with small decision cycles embedded in larger, but very similarly structured ones, and with individual choices made within the confines of a hierarchy of prior, larger scope individual or group choices." (1998: 116) Thus, while understanding individual learning cycles per se is important, they form only a part of the overall picture of the knowledge flow process. To generate a more complete understanding of the flow of knowledge within the global innovation process requires a parallel understanding of this process' elements. Thus, our focus is on understanding the constituent elements of such a learning cycle and how knowledge characteristics change and flow throughout the entire innovation process.

In sum, while a considerable amount of research has been conducted on knowledge transfer, little investigates the knowledge creation process in the context of cross-boundary innovation. And, although some researchers have speculated about how knowledge flows throughout the phases of the cross-boundary innovation process (cf. Leonard and Sensiper, 1998), there has been a lack of empirical research on this issue. Thus, the purpose of our research is to initiate a dialog that will address these shortcomings. Specifically, our study focuses on three issues. First, we investigate the larger context within which knowledge flows in the innovation process. Second, we seek to understand how highly complex and ambiguous knowledge is integrated over time. Third, we examine the question of how knowledge flows across both internal and external organizational boundaries.

METHODOLOGY

Our research examines the knowledge transfer process within the context of a radical innovation effort. Accomplishing this objective required the use of a methodology that was capable of capturing this dynamic process (Leonard-Barton, 1992) and that reflected the complex interaction of individual, group, and organizational behavior in accessing, creating, and transferring knowledge. Moreover, the process description had to be at a level of detail that would provide understanding of individual, group and organizational behavior over time.

To develop insight into the broader knowledge transfer process, we employed a grounded theory approach. Such an approach 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. A grounded theory approach is particularly well suited to aid in the understanding of the impact of contextual elements and the effect of key actors on this knowledge transfer process over time.

Data Collection

We conducted a longitudinal case study of a new product development effort that took place globally. Case studies are particularly appropriate when the focus is on "how" and "why" questions (Yin, 1994). A case study is also appropriate for understanding the interacting factors that impact on the global new product development 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 interviews. We conducted one 1½ hour telephone interview. We conducted a total of 26 semi-structured interviews with 22 individuals. These interviews lasted on average 1 to 1 ½ hours. Interviews were conducted with nine individuals in the home organization in the US (we use the term home organization to refer to the organization that initiated the new product development effort), seven individuals in the US organization's subsidiary in Ireland (we refer to this subsidiary as Galway), three individuals with a complementor in England, and three individuals with a customer in the US (see Table 1). We use the term complementor here because this company was not just a supplier of technology to the home organization, but also worked very closely with Galway to develop and integrate the complementor's technology into the new product. It was much more than a simple vendor relationship.

[Insert Table 1 here]

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 is the best data collection procedure for our research. Moreover, studies suggest that managers are more likely to agree to be interviewed, rather than complete a questionnaire, especially where the interview topic is seen to be interesting and relevant to their own current work (Lawrence 2000). An interview provides them with an opportunity to reflect on events without needing to write down responses.

Interviews were conducted over a two year time frame by four faculty researchers. Key informants were interviewed twice and the head of Galway was interviewed formally three times. Analysis and sense-making of the data took place over 2003 and 2004. During this period we followed-up with discussions on key issues with this individual several times to clarify points raised in interviews. Based on accepted grounded theory methodology (Stake 1995; Erickson 1986; Eisenhardt 1989; Brown & Eisenhardt 1997; Strauss & 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 Galway, 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

Data analysis began by reconstructing the case of the evolution of Galway's development of new 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 interviews and the data which resulted from the interviews were given equal emphasis in this process (Stake 1995). From this analysis, we were able to refine our thinking about the key patterns of the global new product development process.

Following our preliminary analysis and sense-making, we provided feedback to individuals 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 feedback sessions were interactive and allowed us to reach a deeper understanding of the issues involved.

FINDINGS

Events Leading to the Innovation Effort

In 1993, several senior managers in Digital Equipment Corporation's corporate headquarters in the U.S. tried to encourage supercomputer development as part of an effort to create a market for one of their key technologies. This effort was located in Galway, Ireland. According to the head of the Galway program,

> At that time, [several senior managers] in the U.S. were looking for a way to get a high performance computing program started within Digital. This was to try and make sure Alpha as a technology was successful in the marketplace and high performance computing was an obvious target market for Alpha. [Digital] started to come under severe budget pressure at that time. There was still a strong element of downsizing and consolidation within Digital. At that time, downsizing was happening in the U.S. on a weekly basis. It was very difficult in that environment to think about starting something new. In this climate it made sense to "stash it somewhere where it can't get hurt easily."

Thus, while Galway had the support of several senior managers at the company's US operations, these managers had no corporate mandate to enter the supercomputing market, no business plan, no development plan, no established customer contacts, and insufficient technology prowess in high performance technical computing to initially interest customers. Indeed, the only 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." To the Galway team, success of this project meant possible survival.

Findings

Our findings suggest that the creation and integration of complex and ambiguous knowledge proceeds through a series of three relatively distinct phases in the larger knowledge acquisition and generation cycle. The findings also suggest that each phase is distinct in terms of the way it evolves 1) to meet the needs of the organization 2) the purpose it serves for knowledge integration, and 3) the means it employs to achieve knowledge acquisition and generation goals. In each phase, the innovation team was driven by the organization's needs. These needs, in turn, determined the knowledge transfer goals and the critical knowledge transfer issues within each phase.

Table 2 presents a summary of our findings regarding the organizational needs, knowledge goals in each phase, and critical knowledge transfer issues. We elaborate these findings below.

[Insert Table 2 here]

Phase 1

Key Organizational Needs

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." Thus, achieving clarity about how to become the leader in supercomputing was of paramount importance. In addition, several previous competitors in the supercomputer industry, who had achieved initial success, had been unable to sustain that success. Galway needed to learn how to avoid that path. The need in Phase 1, then, was to learn how to enter, compete effectively, and sustain the Galway team's position in supercomputers.

Key Knowledge Transfer Goals

The key knowledge transfer goal in Phase 1 was to develop an understanding of the technologies that were being used in current supercomputing products and applications. The team was not, however, interested in simply understanding technology for technology's sake. Instead they were interested in using this understanding to develop products that would ultimately generate profits for the corporation. To achieve this objective the team needed an understanding of relevant technologies. They also needed thorough knowledge of customer needs and problems so that their acquired technological understanding could be directed toward the development of a commercially viable product. Therefore, the team had to develop absorptive capacity that would enable them to understand such technologies and customer characteristics.

Critical Knowledge Transfer Issues

Galway was anointed as being the high performance computing group. Yet it's team members didn't start out with knowledge of customer needs or the technical expertise required to develop high performance computing products. Thus, the critical knowledge transfer issue in Phase 1 of the innovation effort was to build and develop competence among a small, core team of individuals most of whom were located in Galway. Developing absorptive capacity in the context of a radical innovation effort entailed developing the ability to understand the implications – both commercial and technological – for new technologies.

We refer to Phase 1 as "wandering in the wilderness" because the team had little idea of where to go for knowledge and what knowledge would be useful to them. Different members of the team fanned out into their environments to search for knowledge that might potentially be useful at some (undefined) later stage. This was accomplished by prospecting for knowledge and by learning what they didn't know. Thus, they were able to develop the absorptive capacity about technical and commercial issues that they would subsequently need to consider for an innovative product development effort.

Developing Technical Competence. The recent downsizing of the parent company and the small size of the pre-existing organization in Galway meant that it was necessary to go outside the Galway organization and hire individuals with technical skills. While just what expertise was going to be required was not clear, a group of individuals, who had a high degree of (basic) technical competence was identified and brought into the Galway group. These individuals subsequently were allowed to wander about the corporation looking for technologies that were interesting. A senior engineer was selected to work with a group of Digital (US) engineers. He discovered that this group was using very interesting technology for a niche market that did not leverage the technology's potential. It was the senior engineer's belief that this technology was fundamentally important and could lead to the development of products for which there was a large market. The Digital engineers initially rebuffed his suggestion that he work with them to develop the full extent of this technology. They finally relented and allowed him to work with this technology on his own. Thus, to develop technical competence in Phase 1 the Galway team hired new members to create technical exchanges within the firm's US operations and across its technical disciplines.

While several writers in the field of new product development have advocated for co-location as a means of facilitating knowledge transfer, it was not appropriate in this situation (Kahn & McDonough 1997). Individuals with knowledge needed for this innovation effort were located on both sides of the Atlantic and needed to maintain their local ties. Moreover, the informal nature of this project meant that it was difficult to relocate established managers. In addition, as pointed out by the Director of the Galway group, "If you co-locate you tend to get inbred and there is a tendency not to look outside." Thus, resource dispersion was what the

Galway team needed to maintain in order to expand their knowledge base . This resource dispersal also allowed Galway to develop the absorptive capacity to eventually reach the understanding needed to create new products. The senior engineers in the Galway group were explicit: it is a "good thing for engineering groups to have to keep one eye beyond the four walls – having groups in multiple locations helps to do that, and Ireland as a country is forced to do that."

Developing Commercial Competence. Customers in this business require "benchmarking" tests so that they can evaluate the performance of products in their particular environment and for their specific task before a purchase decision. In Phase 1, Galway offered to provide such benchmarking tests for free to customers. Through this benchmarking activity, the team began to find out what it didn't know. Customers described their needs and the team applied their existing technological understanding in the benchmarking process. This enabled the team to understand what customers' current products were capable of and why. The Director of the Galway group elaborated.

> In terms of getting started, we cast a fairly wide net in terms of what we would do. We made a definite decision, initially, to do things that were close to customers. One of the things that was an obvious thing to do was benchmarking. Any competitor procurement would involve a competitive benchmark. The customer gives you a selection of his favorite applications and asks how fast can you run them. It was a good way for us to get started and to get some connection with the customers and the people actually selling to those customers.

In addition to learning about customer needs, the Galway group acquired knowledge of applications by hiring people with such experience. These people came from external and internal sources.

> We felt we needed people who actually understood the customers and the applications. Some of these applications would be quite inscrutable to the layman. We felt by bringing those people on board, first of all, we could combine the knowledge of the applications with the knowledge of the computer systems, the Alpha systems, to deliver the best possible results on benchmarks, and also have those people influence what we're doing in terms of product development.

Phase 2

Key Organizational Needs

In Phase 2 the key organizational need shifted. Whereas in Phase 1 the key need was to learn how to lead in supercomputers and to develop a viable economic model, in Phase 2 a key need centered on developing a custom designed product in order to generate a strong reputation in supercomputing. A concurrent, but no less important need was to generate a revenue stream sufficient to support the development effort. Organizations cannot fund prospecting activities indefinitely. Revenues from selling products to customers are required to provide a source of funding for the continuation of the development effort. At the same time, reputation and revenues provided Galway with legitimacy within the rest of the organization during the development process.

Knowledge Transfer Goals

In Phase 2 the key knowledge transfer goal evolved as well. Whereas in Phase 1 the key goals were to build and store technical and customer knowledge and to develop absorptive capacity for new areas of knowledge, in Phase 2 the key goals were to draw from stored knowledge and integrate new knowledge in order to create a state-of-the-art product that surpassed prior competitive offerings. This new goal required the Galway team to use knowledge they had acquired in Phase 1, to integrate it with new knowledge, and to create new knowledge with which to develop higher performance products. This happened primarily through the interaction that occurred between the team and lead users and between the team and a key technology complementor.

Once the members of the Galway team acquired a great deal of technical and market knowledge from the wide net they had cast in Phase 1, they narrowed their focus tightly to work closely with a very select group of users and technical allies. The Galway group head described these lead users as lighthouse accounts "who will tell you how to be successful." The initial set of lead users were government laboratories. The engineers at these labs were some of the most sophisticated users of technology in the world. And, they were among the most demanding users of technology, as well.

> The great thing is you go to [the lab] and you're working at your Alpha server, all the competitor's stuff is around you. You get the scope of what's good or what's bad about your competitors' systems. These guys will tell you how to be successful. They've been in this business for longer than we have. They get Serial Number 1 of every new machine that comes out. That's a very important place to spend time.

The knowledge integration required for creation also depended critically on interaction between the Galway team and a British firm that became a technology complementor. One of the lead customers introduced the Galway team to this complementor that had superior interconnect technology, a critical element of the new product. Integration of the Galway team's and the complementor's technologies to create a product that met the lead customer's requirements became the central goal of Phase 2.

Critical Knowledge Transfer Issues

A Phase 2 critical knowledge transfer issue was leveraging the absorptive capacity for new technology learning that the team had developed in Phase 1. Doing so required the Galway team work seamlessly with the lead customer and complementor to integrate the market and technological knowledge of all three organizations. The lead customer had specific uses for the new product, and different technologies to apply to the new system. Such customer knowledge was markedly more specific than the broad requirements the organization had encountered in Phase One. Furthermore, the technological knowledge being acquired and developed in Phase 2 was considerably more tacit than the knowledge of Phase One. To share and leverage such tacit knowledge, the Galway team had to work face-to-face with the lead customer. Similarly, to leverage absorptive capacity that the team had developed in Phase 1 the team had to work very closely with the complementor to facilitate the integration of tacit technological knowledge.

This tacit knowledge integration among the Galway team, the lead customer and the complementor, was accomplished through 1) periodic physical co-location of key engineers for an extended time 2) frequent face-to-face meetings, and 3) continual communication among team members, the lead users, and the complementor.

In sum, in Phase 2 the critical knowledge transfer issues became those of leveraging the absorptive capacity that the Galway team had acquired in Phase 1, as well as knowledge integration. As the innovation effort moved from Phase 1 to Phase 2, the emphasis also shifted away from individual member general technical knowledge acquisition about supercomputing, i.e., creation of absorptive capacity. Instead, knowledge acquisition became re-focused at the team level through individual interactions. The interactions leading to knowledge acquisition spanned national and corporate boundaries and took place within a network of managers and engineers of the Galway team, their lead customers, and of the complementor.

Phase 3

Key Organizational Needs

The organizational needs in Phase 3 were to commercialize the product by meeting the needs of customers other than the specialized lead users and to generate sustainable profit while keeping the innovation process intact. This required the company to sell stable, routinely produced supercomputers to commercial customers for commercial profit margins.

The custom product developed in Phase 2 served as the template for the manufacture of commercial products. As the Galway head pointed out, "in the end, there's no point in doing these lighthouse accounts at low margin if you can't actually generate real business at margin elsewhere." Generating "real business at margin" required the efficient commercialization of the products that were developed in Phase 2. At the same time the Galway team needed to continue to innovate. They needed to develop state-of-the-art products that would maintain their superior reputation in the supercomputing industry and would provide the basis for future generations of commercial products.

Key Knowledge Transfer Goals

One of the key knowledge transfer goals for the Galway team was to transfer knowledge required for stable, commercial machines from the innovating team to the commercialization "team." This commercialization team included managers and engineers from the firm's sales, manufacturing, and service units. The knowledge to be transferred from the Galway team of innovators to the firm's commercial units consisted primarily of product specifications, i.e., codified knowledge.

At the same time, there was a second key knowledge transfer goal, which was to continue the successful development program they had created in Phase 2. As we will see below, achieving both of these goals required the bifurcation of the organization.

Critical Knowledge Transfer Issues

In Phase 3 there were two sets of critical knowledge transfer issues and actions. One set revolved around using existing knowledge for the purpose of replicating the manufacture and commercialization of the product, and using standardized routines. Another set revolved around maintaining the Phase 2 innovation activities. Both actions were required in order to generate a profit by efficiently commercializing a stable new product and to develop new state-of-the-art products.

By this Phase, the transfer of knowledge expressed in routines was essential to achieving profits. The development group learned how to frame and express their knowledge in explicit routines so that it could be effectively conveyed to the commercial groups in the company. This learning required some initial travel and face-to-face meetings with key members of the commercialization team, so that the Galway group could understand what the commercialization team needed in order to be effective. Those meetings involved significant reciprocal learning, expressed by the Director of the Galway group as "We kept saying 'But our product is different', and they kept saying 'No, these are the rules'." After those initial meetings had resolved the rules, the Galway group sent explicit knowledge to the commercial team through routine corporate channels and normal organizational processes. Effectively, these key members of the company's commercial sales, manufacturing and service units became the buffer and bridge for the Galway group with which they had interacted. In their buffering role, the commercial team's key staff isolated the innovators from a myriad of routine problems that commercial customers may have had. Conversely, in their bridging role these key commercial staffers became the eyes and ears that allowed the Galway group to gain current knowledge of evolving commercial market needs. Members of the commercial team in this bridging role could also bring to the commercial market any relevant new ideas developed by the Galway innovators.

The other set of critical knowledge transfer issues and actions revolved around generating state-of the-art products. To be effective at this task required that the development be isolated from the commercialization process. As the Director noted, the team did achieve the separation necessary to their innovation task.

> We have machines [products] going out that we don't touch. The guys here [the Galway team] wouldn't even know about them. It does prove that we're getting towards what approximates to a product business.

This separation was enabled not only by members of the commercialization team, but also by the senior manager in charge of this effort, who resided in corporate offices in the US. It was critical to ensure that the Galway team was buffered in order to provide them with sufficient time to focus on the development of new products. While providing service to customers is critical, if the Galway team were to spend too much time on this activity, it would detract from engaging with lead customers who were key in the learning process.

DISCUSSION

Much of the prior research on knowledge transfer has focused on the transfer of knowledge from expert sites to novice sites, e.g., from one franchise store to another, and the transfer of routine knowledge, e.g., drawing standards or step-by-step procedures for how to process a commercial loan. In addition to routine knowledge transfer, many organizations have a critical need to find, create, and integrate highly complex and ambiguous knowledge.. Yet, current frameworks do not place their emphasis on how knowledge transfer and learning cycles work when knowledge is complex and ambiguous, nor do they examine these cycles over time. The need to understand such transfer and learning cycles is especially acute for firms that engage in new product development where tasks are inherently complex and ambiguous and the knowledge transferred is often tacit (Cummings, et al., 2003; Brockman & Morgan, 2003; Lam, 1997; Schulze & Hoegl, 2006).

In our investigation of learning cycles over the duration of a radical innovation project we were able to isolate the specific knowledge needs, goals, and activities that occurred in the project's different phases. We were also able to see how these knowledge needs, goals, and activities evolved over time. Figure 1 presents an overview of the learning cycle for the radical innovation that we studied and illustrates the direction of knowledge flow over time.

[Insert Figure 1 here]
]

Perhaps our key finding is that the structure of the learning cycle, the direction of knowledge flow, and the content and type of knowledge flowing all differed from one phase to the next, i.e., there was not a single type of learning cycle that applied in all situations. Further, the key knowledge needs, knowledge transfer goals, and knowledge transfer issues and actions appeared to influence the 1) structure of the learning cycle 2) knowledge flow direction and 3) content and type of knowledge in question.

As Figure 1 illustrates the cycle of learning is much more complex than prior researchers often suggest. Within the overall innovation process are a series of learning cycles, each with their own characteristics. As well, the purpose of these cycles differs throughout the innovation process. Prior research, which implies a single form of learning cycle, may mask the purpose served by the learning that occurs in each phase and the different characteristics that result. In sum, while there are learning cycles in each phase, each is somewhat distinct.

Figure 1 also suggests that knowledge transfer is much too passive a term for the activity that takes place within these cycles. As Spender (1996) suggests, "the prevailing notion of knowledge seems naively positivistic and that of learning simplistically mechanical. We seem to presume that knowledge is made up of discrete and transferable granules of understanding about reality which can be added to an extant heap of knowledge." He argues instead, that we need to think of organizational knowledge, learning and memory "as interrelated parts of a single system." Doing so is made easier when we consider the overall, larger learning process as being one consisting of multiple phases, each with different needs, goals, issues and actions. And within these phases knowledge, or what Teece (2001) refers to as intangible assets, is generated, acquired, transferred, and combined.

Knowledge, Learning, and Memory

In Phase 1 of the innovation process, exploration was the central activity of the Galway team. Learning what they didn't know and developing the absorptive capacity to enable them to learn new knowledge were critical. And, as shown in Figure 1, doing so meant bringing in knowledge from the outside and into the team. More specifically, it meant having individuals go to where the new, potentially useful knowledge resided and acquiring, learning and absorbing that knowledge. This process took place over about a 12 month period.

At this phase of the innovation project the flow of knowledge was very much one way - from outside the team in, i.e., it flowed <u>from</u> customers and technologists within the corporation <u>to</u> the development team. Thus, to identify technologies that would potentially be useful and to identify customer needs required that the Galway team find sources of knowledge and incorporate it into their own thinking and their own knowledge repertoire. We see this in the instance where the team sought out customers for whom they could benchmark. The deliberate strategy of performing benchmarking for customers resulted in the team learning about customer needs and problems and was a way of building upon their existing knowledge. In another instance one of the senior engineers on the team went to the US to work, face-to-face, with an engineer to develop an increased understanding of the technologies that were being worked on in another part of the corporation. In both cases, the understanding that resulted from these activities was stored in organizational memory in the sense that knowledge acquired by individual team members was subsequently shared with other members of the team. While much of the knowledge being acquired was relatively explicit, it required that the team or the individual team member be able to ask lots of questions, and apply what they already knew to the new situations presented by the customers. Thus, while this was not a passive transfer of knowledge from the customer to the team, knowledge flowed primarily from customers to the Galway team.

The rate of knowledge acquisition at this stage was relatively slow because the team had limited knowledge to begin with, i.e., their absorptive capacity was relatively small (Lane & Lubatkin 1998). This was due in part to the fact that the interactions between customers or the engineer and the team were "long-cycle" interactions. For example, the team approached a customer about benchmarking, the customer agreed, the team would perform the benchmarking, the customer would react and the team would learn a bit. The amount of learning was relatively modest and the interaction cycle took place over a period of months.

The characteristics of the learning cycle differed considerably in Phase 2. This Phase was marked by the team beginning to use the reservoirs (Argote & Ingram 2000) of knowledge that they accumulated in Phase 1 to develop their first "fast" computer. This product, which they dubbed Turbozilla, was developed by the Galway team with virtually no input from sources outside the team, i.e., this product marked a point of convergence in the team's learning and in some sense was an exploitation of knowledge that had been acquired and stored in the previous stage.

But as we move further through Phase 2, it became obvious to the team that they lacked sufficient knowledge in order to develop products that would compete in the supercomputing market space. Further, the type of knowledge that the team needed was different from the type of knowledge in Phase 1. Whereas the knowledge in Phase 1 was uncertain and complex, in Phase 2 the knowledge was ambiguous and equivocal and thus likely to have significant tacit components (Nonaka 1994). Knowledge that is equivocal has multiple meanings for or interpretations of the same thing (Zack 2001; Aristotle 350BC; Shannon 1949; Dretske 1981; Daft & Macintosh 1981; Machlup 1980; Weick 1969), while knowledge that is ambiguous makes it difficult to interpret or make sense of something (Machlup 1980; MacKay 1969; Weick 1969). It should also be noted that the issue of what constitutes complexity has been hotly debated. For example, Fishman (2005) points out that using rule-based skills to perform complex but discrete tasks does not equal highly complex knowledge. We would argue that "integrating bits of technology" – a key goal for the Galway team, is not only complex, but is also highly ambiguous.

In more radical product development efforts, where technologies are new or untested in the current application, we would anticipate that ambiguity and equivocality would be high in response to a lack of codified knowledge and agreed to "best practice." As Zack (2001) notes, "Each individual, having a unique, tacitly known set of experiences, values, and knowledge, will tend to interpret events differently (Weick 1969),. …[I]n cases where tacitly held process knowledge cannot be clearly articulated or unambiguously communicated to another person, multiple interpretations of how something should be done emerge, often resulting in no clearly unique best approach to a process (Bohn 1986)." Thus, the ambiguity and equivocality that arises in a radical new product development project create knowledge problems that the firm needs to manage (Zack 2001).

Resolving knowledge problems characterized by either ambiguity or equivocality, by contrast, requires rich and varied expression, which typically mandates "frequent face-to-face communication, and reliance on a flexible and responsive network of personal contacts to serve as a source of knowledge and expertise." (Zack 2001) Thus, in order to generate, acquire, transfer, and combine this knowledge the Galway team needed to work very closely with these individuals and their approach to learning from these customers was extremely interactive (reciprocal).

Thus, whereas in Phase 1 the knowledge transfer took place primarily by bringing in knowledge from outside the team, in Phase 2, knowledge transfer was more of a reciprocal process between developers and customers of the product. And, in contrast to Phase 1, in Phase 2 the team knew with whom they needed to engage in order to the co-create the knowledge they needed to develop a state-of-the-art supercomputer. Now, their focus was on selected "lead customers" (i.e., lighthouse accounts) and a complementor.

The reciprocal learning cycle was a key means of enabling creativity. The extensive amount of time spent face-to-face led to what Kulkki and Kosonen (2001) refer to as a "culture of co-creation," i.e., a culture in which failure led to learning, that was based on competence and egalitarianism, and where rapid decision making occurred.

As noted in the quote below, members of the lab at a lead customer were able to share knowledge with the team, which, in turn, facilitated their ability to create the products that these lighthouse accounts wanted.

> I spent time there on multiple occasions. Before the product existed, they were keenly interested in how it was going to work. At that stage, nothing did exist in terms of products. Lab prototypes existed, but in terms of total system attributes, they weren't there. I think in that phase there was a lot of collaboration because they would say what's going to happen when such and such happens. I said, mmm, how about this? That's a great idea. Or, that's a terrible idea because that's a problem that we had with some other vendor. I worked a lot with [the senior engineer].

At the same time, being physically present at the lab provided additional opportunity for the team to leverage the absorptive capacity that was gained in Phase 1 and in the early part of Phase 2. Specifically, the team was able to evaluate competitors' products, something they would not have been able to do in Phase 1 when they were just beginning to develop an understanding of technologies and customers. At that point the team was focused on building absorptive capacity.

The Galway team also worked very closely with the complementor to develop and integrate the complementor's technology into the new product. The technical and performance benefits of working with the complementor were immediately apparent. The Galway team was able to leverage the absorptive capacity developed in Phase 1 to enable the reciprocal transfer of knowledge between themselves and the complementor. In some sense then, the lead customer and complement were sources of knowledge and learning, on the one hand, and co-developers and co-creators, on the other.

The highly equivocal nature of the technologies and the complex needs of the lead customer, as well as the tacit nature of the knowledge, made it necessary to collaborate with the customer and the vendor. Thus, the dominant pattern of the knowledge flow in Phase 2 was reciprocal. Knowledge flowed back and forth between members of the development team, the development team and the customer, the development team and the complementor, and the customer and the complementor. Absorptive capacity was leveraged by retrieving technological and customer knowledge from the team's organizational memory and then sharing the knowledge among team members and with the lead customer and the complementor. Interactions among the team, customer, and vendor resulted in new knowledge being created, which was then stored in memory, retrieved, shared, stored, and so on. The result of this process was a creative product (supercomputer).

This Phase was also characterized by rapid, high-volume learning cycles. The amount of knowledge acquired, generated, and applied within a 12 month time span was far greater than in Phase 1. This rapid, high-volume learning cycle was made possible by the face-to-face reciprocal nature of the process. The barrier of distance was eliminated, and with it the time barrier. But, perhaps even more importantly, the barrier of relationship was also eliminated as a consequence of the network of interpersonal contacts and social capital that were developed (Lorenzoni & Lipparini 1999; Zack 2001; Nonaka 1994). The head of Galway took a series of very deliberate steps to facilitate the building of very close relationships between the team and the lead customer, the complementor, and engineers in Corporate, including face-to-face meetings, bringing individuals to Galway and by having Galway team members traveling to other the complementors, lead customers, and corporate to work on projects. As the following quote from the lead customer's IT manager suggests, the efforts by Galway to build strong relationships with the lead customer paid off.

> From a technical perspective, we worked well together and we made rapid progress. On a personal level, I liked all those people, and they got along well with our technical people. It was fun!

Phase 3 was marked by bifurcated learning cycles that reflect the dual set of knowledge needs, goals, and activities in this phase. One set revolved around using existing knowledge for the purpose of replicating the manufacture and commercialization of the product, and using standardized routines. Another set revolved around maintaining the Phase 2 innovation activities.

On the one hand, knowledge was being transferred from the Galway team to other parts of the organization for the purposes of commercializing existing, albeit slower, computers. Knowledge that had been stored in organizational memory, including templates, design specifications, and the like, was retrieved by other departments, e.g., manufacturing, service, and sales, and was used to commercialize products in large volumes. Thus, knowledge flowed primarily from the team to other departments in the organization.

At this point, the knowledge being transferred was more explicit and had been codified in the form of plans, specifications, drawings, etc. This situation is similar to the kind of knowledge transfer activity that other researchers have studied (Szulanski 1996; Argote, Beckman, & Epple 1990; Darr, Argote, & Epple 1995) While some interaction occurred between these other departments and the Galway team, the team was deliberately shielded from mundane inquiries in order to be able to focus on the development of the next state-of-the-art product. Thus, very little learning was taking place between the Galway team and the commercialization team.

On the other hand, while being buffered from the commercial side of the business, the Galway team continued to work closely with lead customers in much the same manner as they had in Phase 2 and for much the same purpose. Not surprisingly, this resulted in a reciprocal learning cycle that mirrored the one found in Phase 2.

CONCLUSION

Our research suggests the value of taking a "finer grained" view of the knowledge transfer process as it pertains to a radical innovation effort. This finer grained view suggests that it is important for researchers to identify the phases in the overall knowledge transfer process and to look at the learning cycles occurring inside each of these phases. Further, our research suggests that it is important for researchers to take into account three essential elements in the knowledge transfer process, 1) the key drivers of each phase in the process, 2) the purpose served by each phase, and 3) the knowledge transfer issues that are critical to each phase. Equally important is the need to consider the affects of these key knowledge needs, knowledge transfer goals, and knowledge transfer issues and actions on the structure of the learning cycle, knowledge flow direction and content and type of knowledge in question.

It is important to emphasize that the nature of our research is exploratory. While we have identified and analyzed the learning cycles within the context of a radical new product development effort, it remains for future research to determine whether these learning cycles describe other types of innovation efforts and learning cycles more generally.

Finally, future research must investigate in more detail the impact and implications of not only cross boundary knowledge flow, but also cross culture knowledge flow. Though our research required crossing national borders, it was conducted in on organization whose corporate cultural heritage was strong (Digital Equipment Corporation). Also, the managers' national cultures involved in this study have small cultural distances. Very little research has explored the effect of culture on learning cycles and the steps that can, or need, to be taken to facilitate reciprocal learning when individuals are form distinctly different national cultures.

In sum, we believe that this research has furthered the understanding of knowledge transfer in the context of an innovation process. Future research is likely to benefit from taking into account the characteristics of the different learning cycles for different phases in the knowledge transfer process and the implications that these have for facilitating knowledge acquisition, creation, and integration.

REFERENCES

Argote, L. 1999. *Organizational Learning: Creating, Retaining and Transferring Knowledge*. Kluwer, Norwell, MA.

____, P. Ingram. 2000. Knowledge transfer: A basis for competitive advantage of firms. *Organ. Beh. Human Decision Processes*. 82 (2) 150–169.

____, S. Beckman, D. Epple. 1990. The persistence and transfer of learning in industrial settings. *Mgt. Sci.* 36 140–154.

Aristotle, Categories, 350 BC, Translated by E. M. Edghill, http://webatomics.com/Classics/Aristotle/

Bjorkman, I. W. Barner-Rasmussen, L. Li. 2004. Managing knowledge transfer in MNCs: the impact of headquarters control mechanisms. *J. of International Bus. Studies.* 35 443-455.

Bohn, R. E., "An Informal Note on Knowledge and How to Manage It", Harvard Business School Case Services, 1986

Brown, S.L., K.M. Eisenhardt, 1997. The Art of Continuous Change: Linking Complexity Theory and Time-paced Evolution in Relentlessly Shifting Organizations. *Admin. Sci. Quart.* 42 1-34.

Carlile, P.R., E.S. Rebentisch. 2003. Into the Black Box: The Knowledge Transformation Cycle. *Mgt. Sci.* 49 1180–1195.

Cohen, W.M., D.A. Levinthal. 1990. Absorptive capacity: A new perspective on learning and innovation. *Admin. Sci. Quart.* 35 128-52.

Daft, R. L. & N. B. Macintosh. 1981. A tentative exploration into the amount and equivocality of information processing in organizational work units. *Admin. Sci. Quart.* 26 207-24.

Darr, E.D., L. Argote,, D. Epple. 1995. The acquisition, transfer, and depreciation of knowledge in service organizations: productivity in franchises. *Mgt. Sci.* 41 1750-1762.

Dretske, F. I., *Knowledge and the Flow of Information*, (Cambridge, MA: The MIT Press, 1981)

Erickson, F. 1986. Qualitative methods in research on teaching in M. Wittrock (Ed.), *Handbook Of Research On Teaching* (pp. 119-161). New York, NY: Macmillan.

Eisenhardt, Kathleen M. 1989. Building theories from case study research. *Acad. of Mgt. Rev*. 14 232-53.

Epple, D., L. Argote, R. Devadas. 1991. Organizational learning curves: a method for investigating intra-plant transfer of knowledge acquired through learning by doing. *Organ. Sci*. 2 58-70.

Fishman, T.C. 2005. *China, Inc.* New York, NY: Scribner.

Hansen, M. T. 1999. The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge across Organization Subunits. *Admin. Sci. Quart.* 44 82-112.

Hansen, M. T. 2002. Knowledge networks: Explaining effective knowledge sharing in multiunit companies. *Organ. Sci.* 13 232–248.

Hargadon, A. 2003. *How Breakthroughs Happen*. Boston, MA: Harvard Business School Press.

Hargadon, A.„ R. Sutton. 1997. Technology brokering and innovation in a product development firm. *Admin. Sci. Quart.* 42 716–749.

Jensen, R., G. Szulanski. 2004, Stickiness and the adaptation of organizational practices in cross-border knowledge transfers. *J. of Internat. Business Studies*, 35 508-523.

Kahn, K.B., E.F. McDonough III. 1997. An Empirical Study of the Relationships among Co-location, Integration, Performance, and Satisfaction. *J. of Product Innovation Mgt.* 27 163-178.

Kulkki, S., M. Kosonen. 2001. How tacit knowledge explains organizational renewal and growth: the case of Nokia. Nonaka, I., D. Teece, eds. *Managing Industrial Knowledge: creation, transfer, and utilization*. London: Sage. 244-269.

Lam, A. 1997. Embedded Firms, embedded knowledge: problems of collaboration and knowledge transfer in global cooperative ventures. *Org. Studies*. 18 973-996.

Lane, P. J., J.E. Salk,, M.A. Lyles. 2001. Absorptive capacity, learning, and performance in international joint ventures. *Strategic Mgt. J.* 22 1139-1161.

Lane, P. J., M. Lubatkin. 1998. Relative absorptive capacity and interorganizational learning. *Strategic Mgt. J.,* 19 461–477.

Lawrence, Neuman W. 2000. *Social research methods: Qualitative and quantitative approach*. Boston, MA: Allyn and Bacon.

Leonard-Barton, D. 1992. Core Capability and Core Rigidities: A Paradox in Managing New Product Development. *Strategic Mgt. J.* 13 111-125.

Leonard, D., S. Sensiper. 1998. The role of tacit knowledge in group innovation. *California Mgt. Rev.* 40 112-33.

Li, J., O. Shenkar. 2003. Knowledge search and governance choice: international joint ventures in the People's republic of China. *Mgt. Internat. Rev.* 43 91-109.

Lorenzoni, Gianni, Andrea Lipparini. 1999. The leveraging of inter-firm relationships as a distinctive organizational capability: A longitudinal study. *Strategic Mgt. J.* 20 317-338.

Lyles, M.A., G. von Krogh, J.H. Aadne. 2003. Knowledge acquisition and knowledge enablers in international joint ventures and their foreign parents. *Mgt. Internat. Rev.* 43 111-129.

Machlup, F. 1980. *Knowledge: Its creation, distribution and economic significance*. Princeton, NJ: Princeton University Press.

MacKay, D.M. 1969. *Information, Mechanism, and Meaning*. Cambridge, MA: The MIT Press.

McDonough, E.F. III, R.P. Leifer. 1986. Effective Control of New Product Projects: The Interaction of Organization Culture and Project Leadership. *J. of Product Innovation Mgt.* 3 149-157.

Nonaka, I., D. Teece, eds. 2001. *Managing Industrial Knowledge: creation , transfer, and utilization*. London: Sage.

Nonaka, I. 1994. A Dynamic Theory of Organizational Knowledge Creation. *Organ. Sci.* 5 (1) 14-37.

Polanyi, M. 1966. *The tacit dimension*. London, UK: Routledge and Kegan Paul Ltd.

Putnam, R.D. 1993. The prosperous community: Social capital and public life. *The American Prospect.* 13 35-42.

Shannon, C. E., "The Mathematical Theory of Communication", in C. E. Shannon, W. Weaver, The Mathematical Theory of Communication, (Urbana, IL: University of Illinois Press, 1949), pp. 29-125.

Simonin, B.L. 2004. An empirical investigation o the processes of knowledge transfer in international strategic alliances. *J. of Internat. Bus. Studies*. 35 407-427.

Spender, J.C. 1996. Organizational knowledge, learning and memory: three concepts in search of a theory *J. of Organizational Change Mgt.* 9 63-78.

Stake, R.E. 1995. *The art of case study research*. London, UK: Sage.

Strauss, A.L., J.M. Corbin. 1990. *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

Szulanski, G. 1996. Exploring internal stickiness: Impediments to the transfer of best practice with the firm. *Strategic Mgt. J.* 17 (Summer Special Issue) 27–43.

____. 2000. The process of knowledge transfer: A diachronic analysis of stickiness. *Organ. Behavior Human Decision Processes* 82 9–27.

____, R. Cappetta, R.J. Jensen. 2004. When and how trustworthiness matters: Knowledge transfer and the moderating effect of causal ambiguity. Organ. Sci. 15 600-613.

Takeuchi, H. 2001. Towards a universal management of the concept of knowledge. Nonaka, I., D. Teece, eds. *Managing Industrial Knowledge: creation, transfer, and utilization*. London: Sage. 315-329.

Teece, D. 2001. Strategies for managing knowledge assets: the role of firm structure and industrial context. Nonaka, I., D. Teece, eds. *Managing Industrial Knowledge: creation, transfer, and utilization*. London: Sage. 124-144.

Weick, K.E. 1979. *The social psychology of organizing.* New York, NY: Random House.

Winter, S., G. Szulanski. 2001. Replication as strategy. *Organ. Sci.* 16 730–743.

Yamin, M., J. Otto. 2004. Patterns of knowledge flows and MNE innovative performance. *J. of Internat. Mgt.* 10 239-258.

Yin, R.K. 1994. *Case study research: Design and methods.* 2 ed. Thousand Oaks, CA: Sage.

Zack, M.H. 2001. If managing knowledge is the solution, what is the problem? In Malhotra, Yogesh, ed. *Knowledge management and business model innovation*. Boston, MA: Idea Group Publishing.

Table 1

The Interview Sample

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

Table 2

Knowledge Process Findings for a Radical Innovation

	Phase 1	Phase 2	Phase 3
Key Organizational Needs	Learn how to lead in supercomputers, including developing a viable economic model	Develop a custom designed product for reputation and revenue.	Commercialize the product for profit. Sell stable supercomputers to commercial customers for commercial margins. Sustain the innovation process.
Key Knowledge Transfer Goals, i.e., the purpose served by creating and integrating the knowledge	Build and store technical and customer knowledge. Develop absorptive capacity for new areas of knowledge.	Draw from stored knowledge and integrate new knowledge to create a state of the art product.	Transfer product knowledge to commercial team. Maintain state of the art development with lead users.
Critical Knowledge Transfer Issues and Actions	Identifying what knowledge the innovating team needs, and where to find it. This was accomplished by casting a wide net. Selected engineers were sent to work with knowledgeable groups & to run benchmarking tests for customers. Engineers were hired who understood customers and applications.	Leveraging absorptive capacity. This was accomplished by focusing on and working with a narrow, selected group of lead users/clients; working with a technology complementor; acquiring new knowledge via periodic co-location, face-to-face meetings, "butts on planes," and continual communication.	Buffering and bridging the innovation and commercialization processes. Innovation was generated by continuing to develop relationships with lead users and technology complementor. Commercialization was accomplished by stabilizing the product, translating specifications to explicit routines and creating commercial product; selling stable product through the firm's commercial team; buffering the innovating team from the routine problems of commercial customers; bridging innovation and the commercialization process

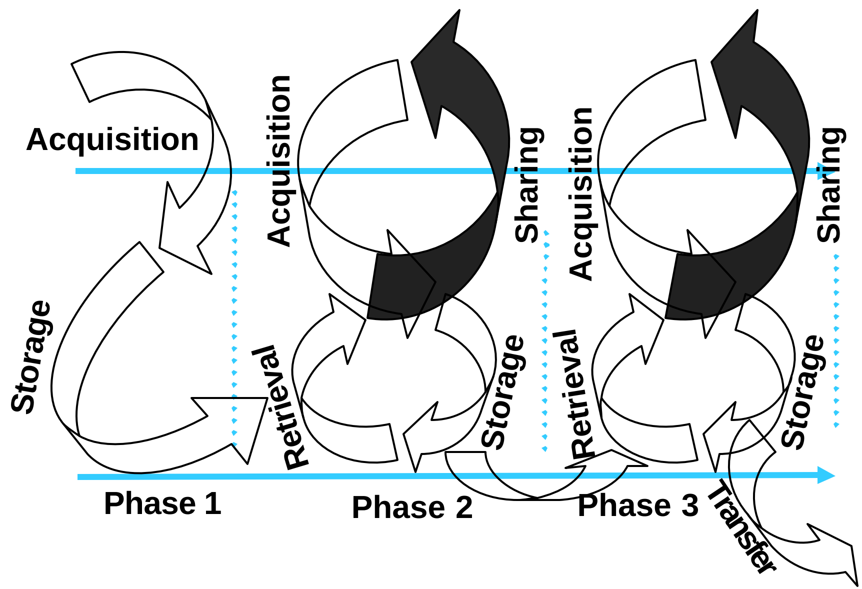

Figure 1. The Learning Cycle for a Radical Innovation