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ESSAYS ON PROCESS LEARNING IN R&D ALLIANCES

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ABSTRACT

This dissertation contributes to research around the question of how companies may improve their R&D processes through collaborative R&D activities. The growing need to gain access to new technologies, the need to share risks and costs associated with the development of new products, and the shortening of market opportunity windows in the ICT industry leads to a rising number of R&D Alliances formed every year. In an industry where the ruling imperative of "innovate or die" has been replaced with "collaborate or die" (Chesbrough 2003, Bruce et al. 1995), improving an organization's collaborative capability is a necessity for survival in the marketplace.

By combining qualitative – a multiple action research case study – and quantitative – an international survey – research methods, the dissertation at hand sheds light on the question of how companies can improve their collaboration capability through inter-partner process learning in R&D Alliances. The theoretical waters that this dissertation navigates spring from the research on inter-organizational learning in R&D alliances on one hand, and on process innovation on the other. Within the many inter-organizational learning theories, the Nonaka and Takeuchi (1995) framework of knowledge sharing and creation became the guiding lighthouse for this research.

The dissertation includes four essays. In the first essay, a set of measures for process learning is developed based on a two-case action research study with three Finnish companies from the telecommunications industry. The cases reveal a set of distinct improvements of collaborative R&D processes: the establishment of joint project planning and evaluation meetings, improved prototyping, improved release management, the establishment of joint milestones, the clear division of tasks and responsibilities, and increased inter-departmental and cross-functional interaction. These findings provide practitioners with a benchmark for improvements in collaborative R&D processes. A subset of these learning results is successfully used to measure process learning in the following three essays. These remaining essays are all based on an international survey amongst 105 companies in the telecommunications industry.

The second essay looks into the process of process learning, by investigating how four knowledge creation mechanisms – socialization, externalization, combination and internalization – function in process learning. To my knowledge the study is the first to test the Nonaka and Takeuchi (1995) model of knowledge creation empirically in the context of inter-organizational learning. The results give strong support to their theory and provide the practitioner with insight into the optimal mix of knowledge transfer mechanisms used for communication in collaborative R&D. The process learning measure developed in the first essay is rated by two independent members of each organization, and validated through inter-rater correlation analysis.

The third essay reports on a descriptive study exploring different approaches to process knowledge creation in R&D alliances. The results show that the alliances developing radical as opposed to incremental innovations differ from each other in terms of various partner-specific and alliance-specific characteristics as well as their process learning outcomes. The group of companies that focused on developing incrementally-improved products were more experienced collaborators, utilized various knowledge transfer mechanisms more often, and also scored higher in all three areas of process learning measured than companies developing new, more radical technologies and products, or companies that did not focus on one kind of innovation, but engaged in developing both incremental and radical innovations.

The fourth essay investigates how the competitive situation, the overlap of organizational knowledge bases and the existence of trust in the collaboration relationship influence the effectiveness of meetings, written documents and transfer of people as means for knowledge transfer. The results suggest that competition positively influences the effect of all three types of knowledge transfer mechanisms on learning. The complementarity of the partner organizations' knowledge bases promotes the effectiveness of Meetings and Documents, and the existence of behavioral trust increases the effectiveness of transfer of people as knowledge transfer mechanisms for process learning.

This research is the first to test the widespread organizational learning model of Nonaka and Takeuchi (1995) empirically, in an inter-organizational setting. The findings support the model, and verify that it can be applied to inter-organizational process learning. Additionally, the study contributes to research by specifically mapping knowledge transfer mechanisms to each phase of the socialization-externalization-combination-internalization process (SECI) developed by Nonaka and Takeuchi. The study also develops and empirically verifies a measure for process learning in R&D Alliances. Previous research often tries to measure knowledge transfer success based on proxies such as improved productivity (e.g. Argote 1999, Arrow 1962), number of new products introduced (Tsai 2001), reduced lead-time and waste (Kalling 2003) or increased share price (Anand & Khanna, 2000). Since these proxies are also influenced by a number of other factors than successful knowledge transfer or learning, this study develops a more direct approach: Process learning is measured through specific improvements in the collaborative R&D process that are acquired and implemented through collaboration with a partner company. For the interested manager, the study provides insight into how the knowledge transfer between two partnering companies can be managed in order to enable successful inter-partner process learning. The dissertation also provides a benchmark for process improvements for collaborative R&D processes.

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Jan Feller

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1 INTRODUCTION

1.1 Background

There is no need to state that the telecommunications industry and companies within face increasing competitive pressures, technological chaos and turmoil. In this environment characterized by hypercompetition, smaller market opportunity windows and diminishing returns for mass products, companies need to innovate in order to stay alive (Bruce et al. 1995).

Companies face the need to gain access to new technologies (Dodgson 1993, Nieminen 1992), the need to share risks associated with the development of new products (Gil and de la Fe 1999), or the fact that the time between the identification of a problem and the need to solve it may not be sufficient for an organization to develop the solution internally (Khanna et al. 1998). As a response, companies especially in the Information and Communication Technology (ICT) sectors increasingly seek partners to perform their product development collaboratively (Bruce et al. 1995). After the boom of mergers and acquisitions in the 1980s and mid-1990s, the last decade has seen inter-firm alliances increasing in popularity (Kale et al. 2000, Gil and de la Fé 1999). However, previous research shows that collaboration can be costly, the expectations of the partners are often not met, and many collaborative projects are terminated unsuccessfully (Bruce et al. 1995). Even though companies engage in collaborations with hopes of reducing cost and development time (Hirvensalo et al. 2003, Bruce et al. 1995), many of them experience that collaboration may be counterproductive especially in these fields. If not managed well, collaborative projects are often more costly and last longer than in-house projects. Still, these same companies engage in collaboration over and over again (Bruce et al. 1995). In this light, developing the capability to collaborate has become an imperative for companies in the telecommunications industry and elsewhere (Doz and Hamel 1998).

A central part of this collaboration capability is a company's process for collaborative R&D. A central way to develop this process and the collaboration capability in general is to learn through collaboration – either by learning directly from the partner, or by creating new knowledge together with the partner. In this context, the creation and transfer of knowledge are the basis for competitive advantage of firms (Argote & Ingram, 2000). While many companies are used to facilitating knowledge sharing and creation within their own organization, the transfer of knowledge between companies is significantly more difficult and often less developed (Argote & Ingram, 2000).

Previous research on inter-organizational learning and knowledge transfer remains often on a relatively abstract or theoretical level. While most of the inter-organizational learning studies either focus on technology, product or market related knowledge or do not focus on any specific knowledge at all, only little research exists on the acquisition of process-related knowledge, i.e. process learning. This research responds to this gap by investigating how companies process-learn, how specific knowledge transfer mechanisms function in the process learning context, and what factors influence the effectiveness of those mechanisms.

1.2 Research Questions and Objectives

This study sets out to answer the following question:

"How does inter-partner process learning take place in collaborative R&D projects, and how is it affected by the product developed and the relationship between the partners?"

The study begins with developing measures for process learning, to be used in the remaining three essays. Previous research measures process learning by using proxies such as shortened lead-time, cost reduction or increased innovativeness (Arrow 1962, Argote 1999, Kalling 2003). Since these proxies are influenced also by a number of factors other than process learning, there is a need for measures that reflect process learning on a more concrete level. In this study, the measures are developed by assessing what *companies perceive as process innovations in their collaborative R&D* projects.

The second essay sheds light on the process of process learning itself, by investigating *how partnering firms may learn to better manage their collaborative R&D processes*. In particular, the paper seeks to apply the Nonaka and Takeuchi (1995) model of learning to inter-organizational process learning. The essay seeks to establish a link between the implementation of four knowledge conversion processes – socialization, externalization, combination and internalization – and the process learning outcome.

The third essay identifies different distinct approaches to the use of these knowledge creation processes in R&D alliances, resulting in differences in the degree to which partners are able to upgrade their collaborative R&D processes. The purpose is to explore *whether these differences can be attributed to various technology, company, product and relationship-specific characteristics*.

The last essay sets out to assess, *how the effectiveness of knowledge transfer mechanisms* used in R&D collaborations is influenced by the nature of the *relationship,* especially the existence of competition, knowledge complementarity and behavioral trust between the collaborating partners. Previous research reports contradictory results on the influence of inter-partner competition on learning. While some researchers state that higher competition acts as an incentive to learn from one's competitor, other researchers argue that it leads to an increased protectiveness, thus inhibiting learning. The complementarity of organizational knowledge bases has also been assessed divergently. Some researchers argue that differences in knowledge bases are positively correlated with inter-organizational learning, whereas others could not find any positive impact of differences in the partners' specialized knowledge. The positive effect of behavioral trust on learning is widely acknowledged, however no research exists on whether the importance of trust varies with the use of knowledge transfer mechanisms.

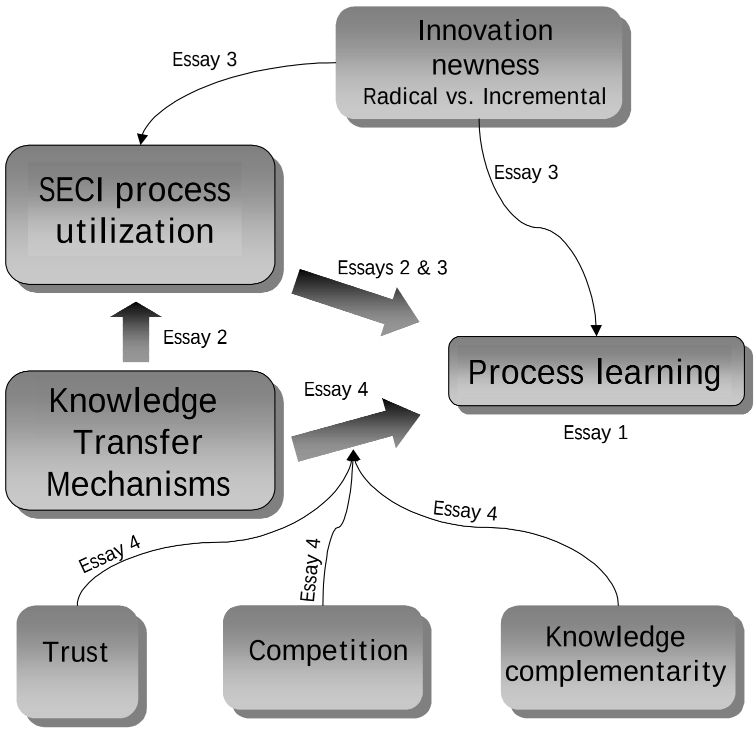

Figure 1: Research Framework and Contributions of the Essays

1.3 Scope and Limitations of the Research

1.3.1 Scope of this research

The industry scope of this research is the telecommunications industry. More specifically, the case study and survey that are the basis for this study were directed to network operators, network equipment manufacturers and suppliers to network equipment manufacturers all over the world. The majority of the respondents, however, are based in Europe and the US. The unit of analysis is a collaborative R&D project conducted jointly by two companies. This project may be conducted as equity-based collaboration such as a joint venture or as more informal collaboration.

The inter-organizational learning process is comprised of up to three subprocesses: knowledge searching, knowledge transfer and knowledge implementation (Argote 1999). This thesis focuses on the latter two subprocesses, leaving the process of knowledge searching outside of its scope.

This study is subject to a number of limitations. First, it has been argued that learning processes in general are highly sensitive to the pervasive effect of culture (see, for instance, Glisby & Holden, 2003; Holden, 2001). Thus, a future study is required to explore the emergence of collaborative routines in alliances outside the main geographical scope of this study sample, i.e. outside Northern Europe and the United States. Second, the set of measures for process learning developed through case research is subject to the limitations of the case research method. The set is based on a multiple case study conducted in a specific company context and during a certain point of time. Finally, this study does not measure the effect of improved R&D processes on product innovation or company success.

1.4 Definitions

Several terms in this dissertation require clear definitions, which are presented below:

1.4.1 R&D Alliance

Some researchers have argued for a broad definition of the term alliance in order to allow research on the multiple purposes that alliances may serve (Wathne et al. 1996). Accordingly, Gulati and Singh (1998) define an alliance as "any voluntarily initiated co-operative agreement between firms that involve exchange, sharing or co-development, and it can include contributions by partners of capital, technology or firm-specific assets." In the context of this thesis, an R&D alliance is defined as a dyadic, co-operative relationship which is based on a formal or informal collaboration agreement and that has the aim of developing a new product or technology to be used by one or both partners, or adopting a new technology for future use by one or both partners. The words R&D collaboration and R&D alliance are used interchangeably.

1.4.2 Process

A process is defined as a series of actions or operations conducing to an end, or a sequence of steps that transforms a set of inputs into a set of outputs. Going further, Ulrich and Eppinger (1995) define a product development process as "the sequence of steps or activities that an enterprise employs to conceive, design, and commercialize a product". In contrast to a project, a process is not unique but it continuously reproduces itself. Additionally, the process does not include the resources of the activities.

1.4.3 Process Learning

Wheelwright and Clark (1992) use the term "know-how", as opposed to "know-what", for describing process-related knowledge. Process learning would thus be the acquisition of "know-how". Chen and Li (1999) define process learning as "to learn the process of engaging and managing cooperation and internal activities". For a more specific definition, process learning in the scope of this study is defined as:

(i) the reception of processes, process improvements or improvements in the prerequisites and ability to learn from R&D collaborations in the future, and

(ii) the implementation of these learnings into the process-in-use.

Process learning leads to process innovation, when the new process-in-use creates added value, i.e. proves over time to be superior to the previous process.

1.4.4 Knowledge Creation Processes

Earlier studies use the term "knowledge creation process" to generally describe the way new knowledge is created (e.g. Fong 2003, Robertson et al. 2003). In contrast to this, other researchers (e.g. Lee and Choi 2003) as well as this study use the term knowledge creation process to refer to the four parts of the SECI process of knowledge creation developed by Nonaka & Takeuchi (1995). The four knowledge creation processes are: socialization, externalization, combination, and internalization. They are presented in more detail in the respective essays.

1.4.5 Knowledge Transfer Mechanisms

Knowledge transfer mechanisms in this context are the tools used by collaborating companies to communicate and transfer knowledge between two collaborative R&D projects. These include for example the various forms of meetings, e-mail, written documents, intranets, and transfer of people. The knowledge transfer mechanisms studied in this research are based on the work of Smeds et al. (2001), and are presented in chapter 2.3.1.

1.5 Structure of this Thesis

This dissertation is organized as follows: The next chapter gives an overview over the relevant previous research as well as points out the research gaps that this thesis is addressing. Chapter three explains the methods used in this dissertation including an overview over statistical methods and criteria. For future survey researchers it also includes a section on findings that have come up during the survey conducted. Chapter four gives an insight into the research findings in the form of summaries of the four essays. The first essay is named "Outcomes of Process Learning in R&D Alliances – Results from Action Research in the Telecommunications Industry" and describes the development of the learning measures through case research. The second essay, "How Companies Learn to Collaborate:

Emergence of Improved Inter-organizational Process in R&D Alliances" sheds light on the *process of* process learning. The third essay titled "Process Learning in Alliances Developing Radical versus Incremental Innovations: Evidence from the Telecommunications Industry" is a descriptive study comparing different approaches to process learning in R&D Alliances. The last essay called "The Influence of Inter-Partner Competition, Trust, and Knowledge Complementarity on the Effectiveness of Knowledge Transfer Mechanisms for Process Learning" assesses how specific knowledge transfer mechanisms are influenced by competition, trust and knowledge complementarity in terms of process learning effectiveness. The appendix provides the questionnaire of the survey conducted for this dissertation, and a summary of the business process simulation method used in the action research conducted for this thesis.

2 PREVIOUS RESEARCH AND RESEARCH GAPS

This chapter provides an overview of relevant previous research in the fields of collaborative R&D in general, process learning, and inter-organizational knowledge transfer. For a more in-depth review of the respective relevant research, please see the theoretical introductions of the essays.

2.1 R&D Alliances

A huge number of alliances are formed every year in transportation, manufacturing, telecommunications, electronics, pharmaceuticals, finance and services. Since many resources necessary for a company to succeed are nowadays found outside the firm's boundaries, the development of a company's collaboration capability has become a necessary imperative (Doz & Hamel 98). Especially in the realm of research and development, collaboration between companies has taken its place as a foundation stone of the R&D activities of many companies (Bruce et al. 1995). Consequently, R&D collaboration in networks is seen to found the 5th generation of R&D (Rogers, 1996).

2.1.1 Motivation

The importance of R&D alliances lies in both the increased innovativeness and the joining of the forces of the alliance partners. Collaborative R&D is usually performed out of one of the following four motives: First, the companies try to access new technology and skills that they do not possess themselves (Dodgson 1993) – so-called alliances of scope (Dussauge et al. 2000). Second, they simply may not have enough resources to perform the desired R&D activities in the specified time (Bruce et al. 1995) – so-called alliances of scale (Dussauge et al. 2000). Third, companies engage in alliances in order to learn (Kale et al. 2000). Fourth, companies need to share the risks and costs associated especially with breakthrough R&D activities (Doz and Hamel 1998). In times of economic downturns, companies tend to engage especially in alliances of scope. In contrast, in times of economic booms, when R&D staff is often working to the limits, firms try to enlarge their capacity and reduce lead-time by forming alliances of scale.

Different schools of thought explain the occurrence of alliances differently: Whereas transaction cost economics mainly explains the occurrence of alliances through the reduction of transaction costs, the resource-based view of the firm finds a different motive for R&D collaboration: If a firm cannot respond to diminishing prospects by using its existing capabilities, a firm may turn to external knowledge sources in order to be able to develop capabilities that diverge from the existing ones (Lane and Lubatkin 1998). The research stream focusing on the knowledge-based view of the firm views alliances as "a means to learn or absorb critical skills or capabilities from alliance partners" (Kale et al. 2000). This latter stream (see e.g. Teece and Pisano 1994, Hamel 1991, Huber 1991) argues that companies may engage in alliances with the sole or primary reason to learn from their partner.

2.1.2 Forms of Collaboration

The most traditional form of collaborative R&D is the joint venture, which however lacks the dynamism, learning opportunities and in-depth-collaboration of more loose alliances (Doz and Hamel 98). On the other hand, research scholars suggest that long-term, equity-based co-operation is better suited for learning tacit know-how and other critical capabilities than contract-based constructs, since the knowledge and capabilities might be embedded in their organizational context (Lane and Lubatkin 1998). Additionally, equity alliances reduce the risk of a firm to lose its core proprietary knowledge to the partner (Kale et al. 2000). While sectors with relatively low levels of technological sophistication have a high share of joint ventures, strategic technology partnering – as it occurs for example in the telecommunications industry – favors the less formal form of contractual arrangements (Hagedoorn and Narula 1996). The even more informal innovational networks – loose organization networks engaged in product and/or process innovation – play a major role in external front-end technology acquisition. Developing an innovation network is strategically relevant if the company is subject to time-based competition and is unfamiliar with a pace technology which is of strategic importance for its core business (van Aken and Weggeman 2000). Innovation networks are mainly based on learning alliances, through which firms can speed capability development and minimize their exposure to technological uncertainties. This is crucial, since in fast-changing industries, the time between identification of a problem and the need to solve it may not be sufficient for an organization to internally develop the solution (Bar and Borrus 1992, Khanna et al. 1998). The least formal way to conduct collaborative R&D takes place in open innovation (Chesbrough 2003). Here, the remaining roles for internal R&D are the administration of meta-knowledge about externally available knowledge, the complementation of this knowledge with the missing pieces, to combine this internal knowledge with external knowledge, and to generate revenues by selling their R&D output to other firms in the open innovation networks.

2.1.3 Success Factors

The success of R&D collaboration is influenced by a number of factors. These include the balance of contributions and outcome for both partners, the provision of adequate resources (Lyons 1991), the existence of personal relationships and trust (Kale et al. 2000), the presence of a 'collaborative champion' (Bruce et al. 1995) or a dedicated alliance function to enable an organization to identify and attract suitable alliance partners (Kale et al. 2002), establishing clear rules for collaboration, intense communication (Bruce et al. 1995), strategic fit of the partners (Harrigan 1985), the ability to manage conflict (Doz and Hamel 1998), and previous collaborative experience (Farr and Fischer 1992, Zollo et al. 2002). Prior research maintains that the capacity to manage collaboration successfully is a distinct capability, termed collaboration-, alliance- or relational capability (see for example Anand & Khanna, 2000; Draulans et al. 2003; Kale et al. 2002). This capability can be developed though incremental learning and fine-tuning (Zollo 1998, Kale and Singh 1999) as well as through newly combining existing knowledge and routines (Zander and Kogut 1995). Researchers assume that firms will be more successful in their alliances, when they continuously develop mechanisms and routines to accumulate, store, integrate and diffuse relevant knowledge related to the management of alliances (e.g. Anand & Khanna 2002, Dyer & Singh 1998). Further success factors positively contributing to alliance capability are relation-specific assets, knowledge-sharing routines, complementary resources, and effective governance (Dyer & Singh, 1998).

2.1.4 Outcome of Alliances

Much research has been conducted on the learning benefits stemming from R&D alliances. Many researchers name the possibility to acquire knowledge from the partner as the main benefit, and even when alliances are formed for other reasons, learning and knowledge acquisition can be a desirable by-product (Child 2001). Alliances bring together complementary expertise and knowledge. This promotes learning both through direct transfer and through the creation of dynamic synergy by bringing together experts with different backgrounds (Child 2001). Cohen and Levinthal (1990) see two factors that act as incentives for learning alliances: The difficulty to learn certain knowledge, and the quantity of required knowledge to learn. On one hand, if industry knowledge is difficult to learn and needs a lot of specialized expertise, the need to invest in R&D is high. Thus, own R&D is more costly and requires more resources if the information available externally is not targeted specifically to the company needs or if it is of tacit nature. This can be an incentive for companies to engage in R&D alliances, in which the knowledge created is often targeted to company needs and tried to be made available in a codified form. On the other hand, the more knowledge there is to learn, the higher the incentive to invest in R&D. If the pace of technological advancement in one field is high, there is more knowledge to learn in order to stay up-to-date, and thus R&D collaboration is more important.

A collaborative R&D project can result in a new or improved product, new technical and scientific knowledge, intellectual property, increased collaboration capability and new or improved internal R&D processes (Ingham and Mother 1998). Out of these, the latter two outcomes are investigated more deeply in the following sections.

2.2 Process Learning

Collaborating companies need to learn in five key areas in order to sustain successful operations: the environment of the alliance, the tasks performed, the collaboration process, the partners' skills, and the alliance goals (Doz and Hamel 98). The focus of this study lies in learning related to the collaborative R&D process, which in turn is a combination of two of the key areas mentioned above: R&D tasks performed as well as the collaboration process.

2.2.1 How Process Learning Takes Place

Collaborative process learning is an inter-organizational learning process, which is based on individual learning (Crossan and Inkpen 1995), but which extends far beyond the mere sum of all individual learning occurring in an organization (Cohen and Levinthal 1990).

According to Child (2001), the knowledge that can be learned in R&D alliances can be classified into three different scopes of organizational application: technical, systemic and strategic knowledge. Technical knowledge refers to knowledge about components, engineering skills and specific techniques such as those for product testing. Learning at this level can be compared to the single-loop learning process mentioned by Argyris and Schön (1978). Systemic knowledge refers to organizational processes and systems. Learning this type of knowledge usually leads to the creation of new roles, processes and restructuring of organizational relationships, and can be compared to double-loop learning. The strategic level of knowledge encompasses the paradigms of senior managers, especially their view on which factors determine the success of their organizations. This study focuses on the acquisition of systemic knowledge, especially organizational processes.

Process learning constitutes thus one of the three learning processes of R&D alliances. But how does inter-organizational process learning happen? Little research has been done on the structure of the learning process between partners collaborating in R&D alliances. In his work on learning through joint ventures, Lindholm (1997) found three different processes that help the collaborating parent companies learn: direct transfer of knowledge, creation of new knowledge in the joint venture, and internalization of knowledge into the parent companies. Direct transfer of knowledge takes place in two ways. On one hand, knowledge is transferred through the joint venture, when one parent company transfers e.g. best practices to the joint venture, from where the same knowledge is transferred unchanged to the other parent company. Alternatively, knowledge can be transferred directly between the two parent companies. The second learning process is the creation of completely new knowledge within the joint venture. Here, learning occurs through the synthesis of the different knowledge inputs from the parent companies. A similar learning process has also been proposed by Nonaka (2000a), who describes the emergence of new knowledge from a joint group context. The last learning process is the harvest by the parent companies: Knowledge that has been generated in the joint venture is internalized into the parent organizations for use in other areas.

While Lindholm investigated general learning processes, practically no studies can be found on inter-organizational process learning. One of the few exceptions is the work of Smeds et al. (Smeds 1997, Smeds and Alvesalo 2003), whose research draws on the Socialization-Explication-Combination-Internalization (SECI) learning model developed by Nonaka and Takeuchi (1995). This model of knowledge conversion integrates the two aspects of social learning and distributed knowledge creation. It was originally developed to analyze the development of product innovations in organizations, but it can also be applied to process innovations and learning (Smeds, 1997). The Nonaka and Takeuchi (1995) model is based on knowledge conversions between explicit and tacit knowledge. This learning model has also become the theoretical base for the essays 2 and 3, and is presented in more detail in these essays.

2.2.2 Measuring the Outcome of Process Learning

When trying to conceptualize process learning in R&D collaboration, the nature of the learning process is one important issue to investigate. However, a second issue, namely measuring the successful outcome of this learning process, is even more challenging and important. It is generally acknowledged that measuring learning is challenging (Argote 1999). Many studies try to measure learning based on high-level proxies such as improved productivity (e.g. Argote 1999, Arrow 1962), number of new products introduced (Tsai 2001), reduced lead-time and waste (Kalling 2003) or increased share price (Anand & Khanna, 2000). These proxies measure improvements in the outcome of the organizational activity. Their advantage is, that these improvements can often be quantified, objectively measured and easily compared. But there is also a downside: the outcome of organizational activity can be influenced by many other factors next to learning. Improved productivity may as well occur due to higher workforce motivation or more efficient machines supplied by vendors. The number of new products introduced is also highly influenced by strategic priorities, competitor moves and market developments. The reduction of lead-time may be influenced by faster production machines or hiring decisions, and increases in share price may be based on unrealistic profit expectations, general hype – as we experienced in the beginning of this decade during the so-called dot-com-bubble – or even on supposedly fraudulent business practices, as shown in the recent financial scandals around publicly noted companies such as Enron or WorldCom.

The previous arguments have lead to the idea that process learning should be measured closer to the R&D process itself. In this research, this is done by letting company representatives assess how distinctive parts of the R&D process have been improved through the collaboration. Since previous research did not deliver suitable measures, the measures used in this thesis were developed through the case research reported in the first essay. To secure the relevance of the measures, the findings were compared to literature on R&D processes (Wheelwright & Clark 1992), and only items concerning relevant parts of the R&D process were included. The items of this measure were rated by two independent members of each organization. The measure was verified since the inter-rater correlation between each pair of answers was significant and high enough.

2.3 Inter-Organizational Knowledge Transfer in Collaborative R&D projects

The actual knowledge transfer is the central part of the inter-organizational learning process, which consists of three phases. The process begins with search for and/or identification of sources of relevant new knowledge. Next, the knowledge is transferred from the "sender" organization to the "receiver" organization. Last, the knowledge transferred is implemented into the organization's routines and structures (Argote 1999). It is thus obvious that knowledge transfer itself is a necessity both for distributed product development within one company (de Meyer 1991) as well as for R&D collaborations.

The recognition of this fact makes it even more astonishing, that there is substantially less research in inter-organizational knowledge transfer than in the realm of knowledge transfer within an organization (Lane 2001). The study at hand addresses this gap by examining the knowledge transfer mechanisms used in R&D collaboration, and the factors that influence their effectiveness.

2.3.1 Mechanisms for Knowledge Transfer

Previous literature suggests, that the use of certain types of knowledge transfer mechanisms is positively correlated with successful knowledge transfer. These types are especially meetings and face-to-face personal contacts such as the transfer of people (Epple et al. 1991, Darr et al. 1996, Ingram & Baum 1997), and to a certain extent various written documents such as lessons-learnt reports or final customer reports (Szarka et al. 2004).

Depending on the focus of research, previous studies provide different approaches to classifying knowledge transfer mechanisms (KTMs) within and across organizations. However, the studies mostly use relatively abstract categories or only the most basic mechanisms. Knowledge transfer has been studied according to the stage of the overall knowledge transfer process during which it occurs (e.g. Szulanski 2000), according to the location of knowledge transfer mechanisms in the organization's environment (e.g. Appleyard 1996), or by measuring the use of KTMs on a relatively coarse level such as face-to-face interaction, telephone, letter or e-mail (Nobel & Birkinshaw 1998). However, only few studies exist that investigate the whole spectrum of KTMs that organizations may use for communication, either internally or in collaboration. A notable exception is the study by Smeds et al. (2001), who investigated the use of knowledge transfer mechanisms for inter-project R&D in a global setting. The numerous mechanisms found in their study became one basis for this research and are presented in the table below.

Table 1: Knowledge Transfer Mechanisms found by Smeds et al. (2001)

Co-location	Simulation Games	Trouble Report
Coaching/Tutoring/Training on the job	Teamwork	Suggestions Box
Corridor talk	Use of prototypes	Lessons-learned Reports
Job Rotation	Milestone Review Meetings	"Project Work Trainings"
Support Teams	E-Mail-Distribution Lists	Components Data Bases
Social Activities	Newsgroups	Product Library (Product Bill)
Involvement of designers in early phase	Education	Process guides / descriptions
Workshops	Lectures, Lessons-learned presentations	Telephone conferencing
Experts, Process Consultants	Process maps / Flowcharts	Video conferencing
Videoconferencing	Customer Reports	Fax
Design Methodology Meetings	Final Reports	E-Mail
Kick-off & Wash-up Project Meetings	Meeting Minutes	Company Intranet
Design Review Meetings	Monthly Progress Report	Project Intranet
Final Meetings	Project Documentation	Groupware (e.g. Lotus Notes,)

2.3.2 Factors Affecting the Success of Knowledge Transfer

Inter-organizational knowledge transfer may be hampered by a number of barriers. Previous research on factors affecting the success of knowledge transfer has focused on three different areas: the nature of the knowledge to be transferred, the characteristics and behavior of sender and recipient, and the characteristics of the relationship between sender and recipient.

Research investigating how the nature of knowledge influences its transferability has come up with a number of partly overlapping factors. These are among others the stickiness of knowledge (von Hippel 1994, Szulanski 1996), the complexity of knowledge (Galbraith 1990), and the embeddedness (for example Prahalad 1993) or tacitness of knowledge (Zander and Kogut 1995, Nonaka and Takeuchi 1995). Child (2001) points out a problem that arises during the knowledge transfer between partnering organizations. When experiences that one partner has gained through their specific actions is transferred to the other partner, the different organizational milieus make the transfer more difficult. The experiential knowledge will have to be codified by the "sending" partner. The codification is naturally based on the existing routines, organizational structure and paradigm of the sender. This knowledge cannot be directly used by the receiving organization, since they do not possess the same organizational "mind-set" and routines. In order for them to be able to learn, receive and implement the knowledge, it will have to be internalized by the members of the organization. Nonaka and Takeuchi (1995) have theoreticized this challenge in their SECI model of knowledge transfer and creation. The process of how knowledge can be transferred incorporating among others the stages of codification or externalization, and internalization is investigated in essays 2 and 3.

The degree to which the product developed differs from the products developed earlier by the company is another factor affecting knowledge transfer between partnering organizations. Radical, breakthrough innovations are critical for the renewal of a firm's competitive position (McDermott and O'Connor 2002). While incremental product innovations usually demand only minor changes to an organizations process, radical innovations often demand the utilization of significantly new technologies and processes (ibid., O'Connor and McDermott 2004). In radical product innovation, managing the relationship with a partnering organization is significantly more challenging. Due to the often critical contribution of the partners – their role in radical innovation is usually to contribute completely new knowledge to the project – managing the project is often much more time consuming (ibid.), team composition differs from incremental innovation team composition and the importance of informal networks for knowledge sharing is significantly higher (O'Connor and McDermott 2004). The question whether companies developing radical vs. incremental innovations also learn differently is the special focus of essay 3.

Besides the characteristics of the knowledge transferred and the product developed, previous research has also identified numerous influencing factors within the nature of the relationship. Organizations may not have the capability to absorb the knowledge available from their alliance partners (Lane and Lubatkin 1998), the alliance members may assume that there is nothing to learn, the cooperating partners may be competitors (Child 2001, p.659), or the partners do not trust each other due to little previous experience of expected opportunistic behavior. The competitive situation may lead the companies into learning races, trying to outlearn their partner (Dussauge et al. 2000). Previous experience in knowledge transfer (Kale et al. 2000, Glabraith 1990) influences its effectiveness as well as the overall learning motivation (Szulanski 1996) and interorganizational cooperation strategy of each partner (Larsson et al. 1998). The existence of behavioral trust is generally positively related to inter-organizational learning (Kale et al. 2000), and missing trust in turn leads to knowledge protection (Larsson et al. 1998).

As becomes clear, there exists a significant body of research concentrating on factors influencing inter-organizational learning in general. However, in order to manage and improve learning between organizations, it is important to know how the nature of the relationship between these organizations affects the knowledge transfer mechanisms used to accomplish inter-organizational learning, and whether different mechanisms are affected differently. Essay 4 contributes to closing this research gap by investigating the influence of relationship factors on knowledge transfer mechanism effectiveness.

2.4 Summary of Research Gaps

The first research gap identified is the lack of research on, and frameworks for inter-organizational process learning. The gap is addressed by applying and empirically testing the SECI organizational learning framework developed by Nonaka and Takeuchi (1995) in the context of inter-organizational process learning.

The second research gap exists in the way process learning is measured. The few previous studies that address process learning use mainly proxies measuring improvements in the outcome of the organizational activity. As these proxies might be influenced by other factors than actual learning taking place, this study develops and tests process learning measures that directly relate to specific parts of the collaborative R&D process.

As for the factors influencing inter-organizational learning, a research gap exists in terms of how specific knowledge transfer mechanisms that are used in communication between collaborating partners are influenced by the nature of the collaboration relationship. This gap is addressed by assessing the influence of competition, knowledge complementarity and trust on meetings, written documents and the transfer of people as means for inter-organizational knowledge transfer.

3 METHOD

The following chapter introduces the methods used for addressing the overall research questions. It starts with a description of how the questionnaire for the survey was developed, continues with a description of the data gathering as well as the statistical methods used for analysis, and ends up with the presentation of some personal learning insights on administering survey research.

3.1 Questionnaire Development

3.1.1 Method Effects in Self-reported Surveys

Survey research in general is based on written self-report measures. It is well known, that for each single item the choice of words, formatting, response options, overall context and order of the questions may have an influence on the answer, thus introducing unwanted method variance (Schwarz et al. 1985, Tourangeau 1992, McLaughlin 1999). For this reason, most constructs in this study are measured by two or more items. In order to further reduce method variance stemming from changes in response options, the same scale (1-7) is used for all Likert scale questions throughout the questionnaire. The influence of context is reduced by un-grouping the items of each construct and distributing them over the questionnaire, as well as by using partly reverse coded items.

3.1.2 Measure Development through Case Research

Previous research did not provide sufficient measures for process learning. Thus, two groups of measures for process learning were developed. The first group concerns general self-reported measures on whether the company has learned from their partner's R&D process, and whether these learnings have improved their own process. The second group of measures is more specific, and has been developed through case research of two collaborative R&D projects, by use of triangulation of methods[1]. The research ended up with a set of improvements – in the use of milestones, release management, prototyping, and in the allocation of tasks and responsibilities – that occurred in the case companies through performing collaborative R&D. The case research was carried out as an action research study, analyzing two collaborative R&D projects. The method of data collection used was the SimLab business process simulation method[2].

The reasons of choosing the case study methodology were the following: First, the research objectives to be met by the case study were of exploratory nature. This made case study a

[1] See essay 1 for an overview on the research methods used.
[2] See appendix for a description of the business process simulation approach used.

suitable research methodology (Yin 1994). Additionally, the events examined are of contemporary nature, since R&D collaboration as a part of a firm's R&D activities are a relatively new occurrence. This supports the choice of case study as the suitable methodology (ibid.). According to Yin (1994), a main weakness of this methodology lies in the poor generalizability of the results, since the findings are based only on a limited set of cases. The impact of this weakness on the result of the case study was minimized by the nature of the research objective: Since the results of this study were to be used in and verified through quantitative survey research, the need for generalization at this stage of the research was minimal. The second weakness mentioned by Yin is the long time frame that case studies usually demand. This problem was solved by the SimLab business process simulation method, which provided in-depth understanding of the case project in a limited time[3]. The measures and their development are presented in depth in essay 1.

3.2 Data Gathering

The data for this study was gathered through an international survey conducted during the years 2002-2003. The targeted population in the survey was the network operators, network equipment manufacturers, and suppliers to network equipment manufacturers in the telecommunications industry in Europe, Northern America and Asia. The sample companies were identified by using company directories, industry associations and trade fair exhibitor catalogues[4]. Before being sent out, the questionnaire was tested both by the employees of the pilot companies[5] and the usability laboratory of Helsinki University of Technology. Data collection started with two rounds of mailings to 517 companies in 72 countries. This resulted in only 20 responses. To increase our response rate, the questionnaire was posted on the Internet. By accessing new databases, we were able to add 126 new companies from Finland, Germany, the UK and the US to the sample. We contacted all potential respondents by phone, after which we sent them an e-mail message containing the link to the survey and some additional instructions. The second round produced the majority of the responses from 85 firms. The data gathering process is illustrated in Figure 2.

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[4] See the essays for an overview over sampling sources, and information on sample composition and data collection process.

[5] The pilot companies include the companies from the previous case studies reported in Hirvensalo et al. (2003) and Feller et al. (Forthcoming).

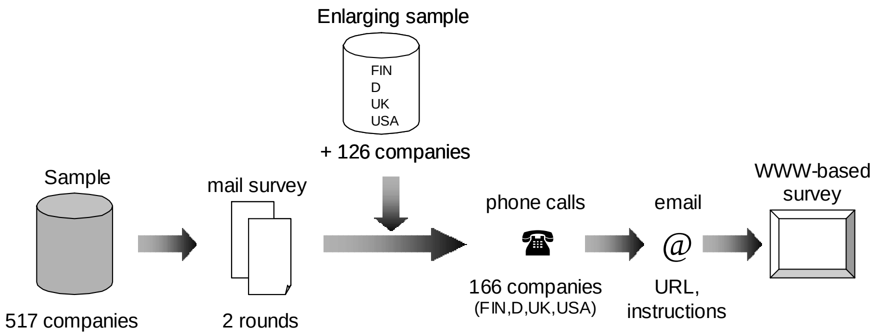

Figure 2: Data gathering process for survey

In order to reduce common method bias, the questionnaire was divided into two parts, to be answered by two individuals. The first part focusing on company-level questions was filled in by the Vice President of Research & Development or the Chief Technology Officer of the respondent company. After filling in the first part, the respondent was asked to choose one of the company's recent but finished collaborative case projects and to forward the second, project-specific part of the questionnaire to the project manager of the case project. Out of the targeted sample of 615 companies, 105 responses were submitted, resulting in a response rate of 17,1%. Besides our respondents being mainly composed of European firms, the non-respondent analysis[6] did not show any significant differences between the respondents and non-respondents in terms of amount of employees, net sales or R&D intensity of the company.

3.3 Statistical methods used

A number of different statistical methods have been used to answer the respective research questions of the essays. Especially in theory-testing research the rigorous use of sound statistical methods is imperative (Boyer and Verma 2000). The methods and criteria used are presented in detail in this chapter.

3.3.1 Multi-rater correlation analysis

A major methodological shortcoming in operation research is the failure to use multiple data sources within one organization (Speier and Swink 1995 ref. Boyer and Verma 2000, Malhotra and Grover 1998). The use of a single respondent from within an organization subjects the research to a possible subjective bias due to an individual's unique perspective and limited information (Jick 1979, Snow and Hambrick 1980). This so-called single rater bias may hamper valid research especially when performance is measured by means of –

[6] The non-respondent analysis was performed using the Kruskal-Wallis test.

subjective – self-reported items (Boyer and Verma 2000). The use of multiple raters from a single organization, while more difficult than using only one respondent, thus increases the confidence of the findings significantly. Following this argumentation, we used two raters from each organization for all performance measures.

When using more than one rater from an organization, substantial disagreement between the raters naturally weakens the reliability of the results. Before the answers of the raters are averaged for each organization, it is thus important to assess, whether the raters agree on the questions asked. The recommended method for assessing this inter-rater agreement in management research is the inter-class correlation (ICC) method (Ebel 1951, Boyer and Verma 2000), which is described in the following. The total variance of the answers given by all respondents from all organizations can be divided into two parts. The variance occurring due to differences in the answers provided by the raters in each single organization is named within group variance (MSW), whereas the variance that exists due to differences between the organizations is called between group variance (MSB). The ICC coefficient assesses for each measurement item, to what extent the variance in the answers is based on between-group variance.

Equation 1: Inter-class correlation coefficient

$$ICC = \frac{MSB - MSW}{MSB}$$

The closer the ICC is to it's maximum of 1, the higher is the portion of between-group variance, and the higher is thus the reliability of the results. In other words, if the ICC is high, the raters within each organization have provided similar answers to an item. Boyer and Verma (2000) propose an acceptable ICC of 0.6. Additionally, the ICC should be statistically significant. Following this proposal, the ICC was calculated in this research for each measurement item rated by multiple raters. Measurement items that showed a significant ICC over 0.6 were then averaged.

3.3.2 Factor Analysis

Factor analysis is a group of methods used for data reduction and summarization with a minimum loss of information (Hair et al. 1995). In other words, factor analysis tries to find the basic constructs underlying the original variables. It is used in this study as a means for verifying construct operationalization. In order to reduce method variance[7], most constructs in this study are comprised of two or more items. These items are intended to measure different facets of the same construct. The factor analytic method used in this study is the principal component analysis method. The rotation methods of the factors used are

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[7] See chapter 3.1.1

orthogonal, as suggested if the resulting factors are used further in regression analysis or other prediction methods (Dillion and Goldstein 1984, Hair et al. 1995). For non-confirmative factor analysis the number of factors was determined by the latent root criterion, i.e. only factors with an eigenvalue over 1 were included. The solutions were then verified with the Scree test. The threshold used for a significant factor loading is 0.6 (Hair et al. 1995).

3.3.3 Multiple Linear Regression

Multiple linear regression analysis is a tool for assessing the relationship between one dependent (criterion) variable, and a number of independent (predictor) variables. This technique is used to test models that help to predict the dependent variable based on the (known) values of the independent variables (Hair et al. 1995). The result is a model containing the relative contribution or weight of each independent variable on the dependent variable. The basic multiple regression model has the form

Equation 2: Basic Multiple Regression Model

$$\hat{Y} = b_0 + b_1x_1 + \ldots + b_nx_n$$

Where Y is the dependent variable, b_0 a constant, x_n an independent variable and b_n the relative weight of that variable.

The main assumptions for using multiple linear regression are the normality of the variables, the homoscedasticity (i.e. equality of variance) of the criterion variable, and the independence of the predictor variables. In this research, the normality of the variables was tested by assessing the normality of the error term distribution graphically with the help of normal probability plots. This procedure is widely used and recommended by experts (Daniel and Wood 1980, Hair et al. 1995). The findings of each assessment were additionally verified by means of the Kolmogorov-Smirnov test for normality.

The homoscedasticity of the variables is tested using Levene's test. This test is robust against departures from normality and thus particularly recommended (Hair et al. 1995). In cases where heteroscedasticity was present, variance-stabilizing transformations were applied in order to achieve equal variances. The use of these transformations is reported for each variable where applied.

The presence of multicollinearity has a substantial effect on the results of the regression analysis, especially because it prohibits determining the contribution of each single variable. The presence of multicollinearity is tested for by calculating the tolerance value or its inverse, the variance inflation factor (VIF). The smaller the tolerance value, the higher the multicollinearity. This study uses the commonly suggested tolerance value of 0.1 as a threshold (Chatterjee and Price 1991, Hair et al. 1995).

Next to the assumptions mentioned above, the existence of outliers – cases that have large residual values – influences the result of the regression analysis (Belsey et al 1984). As suggested by Belsey et al., outliers with standardized residuals greater than 2 were removed from the regression analysis, if the existence of the outlier could be explained, for example through data entry errors.

Mediated Multiple Regression Analysis

Mediated multiple regression analysis is a tool to detect interactions among variables. A mediator represents the mechanisms, through which an independent variable is able to influence the dependent variable. As Figure 3 depicts, two inputs feeding into the outcome variable are assumed: a direct influence from the independent variable, and the impact from the mediator.

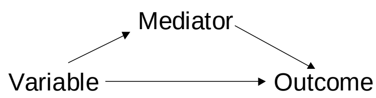


Figure 3: The Mediator Model (adapted from: Baron and Kenny 1986)

A mediating effect is present, if the following three criteria are fulfilled (Baron and Kenny 1986): There has to be a significant relationship between the independent and the dependent variable. Second, the independent variable must have a statistically significant relationship with the mediator. Finally, the previously significant relationship between the independent and the dependent variable must be reduced, when the mediator is entered into the regression model. If this direct relationship between the independent and the dependent variable ceases to exist, this is strong evidence for the mediator being the single, dominant mediator. If the relationship is merely reduced, the existence of more than one mediator is indicated.

Moderated Multiple Regression Analysis

The term moderator refers to a variable that influences the strength and/or direction of the relation between an independent and a dependent variable (Baron and Kenny 1986). If both variables are continuous – as is the case in this study – the moderating effect is determined by introducing an interaction variable into the regression equation. Equation 3 presents the example of an interaction between x_1 and x_2:

Equation 3: Regression with Moderator Variable

$$\hat{Y} = B_1x_1 + B_2x_2 + \ldots + B_nx_n + B_{n+1}x_1x_2 + B_0$$

A moderating effect is present, if the interaction is significant – independent on whether the main effects of the predictor and moderator themselves are significant. In order to be able to clearly interpret the interaction term, it is desirable that the moderator be uncorrelated with both the predictor and the criterion variable (Baron and Kenny 1986, Aiken and West 1991). Cohen et al. (2003) suggest that all predictor variables are centered when using moderated multiple regression analysis. This reduces unessential multicollinearity and allows for easier interpretation of the non-moderator regression terms: With centered variables, the coefficient of each non-moderating predictor depicts the regression of the criterion on that predictor at the sample means of the other regression variables.

3.3.4 Cluster Analysis

The objective of cluster analysis is to find groups of cases (i.e. organizations) that differ from each other in one or more characteristics – the so-called cluster variates. In other words, the analysis forms groups that differ as much as possible, with the members of each group being as similar to each other as possible (Everitt, 1980; Hair et al., 1995; Ketchen & Shook, 1996). However, cluster analysis may lead to misleading results if not carried out with great care. Cluster analysis is the only multivariate technique that does not estimate the variates empirically but uses instead the variate defined by the researcher. Therefore, the definition of the cluster variate should be based upon careful theoretical or empirical considerations. In addition, the results of the cluster analysis are easily influenced by the clustering method used. To reduce this influence and increase the reliability of the research, the use of a two-stage clustering procedure is recommended (Ketchen & Shook, 1996; Hair et al. 1995). The procedure, which has also been applied in this research, includes a double cluster analysis using two different methods. If both methods lead to similar results, the clusters are valid. The two methods used in this study are the complete linkage method, and the k-means method. In the complete linkage method the cluster membership is based on the maximum distance between objects, with all objects linked to each other (Everitt 1980; Hair et al. 1995). The k-means or nonhierarchical clustering procedure used in this study follows the parallel threshold approach. The cluster centers are selected simultaneously in the beginning, and objects within the threshold distances are assigned to the nearest cluster center. As the process continues, the distances are adjusted gradually. This procedure is easily affected by the choice of the initial cluster centers, and it is thus recommended to verify the results by use of a hierarchical clustering method (ibid).

3.4 Some Personal Insights on Conducting Survey Research

The following section contains individual learning points that I have gone through during the survey research for this thesis. The findings are of qualitative nature, and have not been analyzed for any kind of statistical significance. Nevertheless, I think that some of the points listed below might be useful for future researchers and have some implications for survey research methodology.

3.4.1 Developing a Web-based Survey

The survey for this research was developed specifically for this application. The web pages were created with a commercial HTML-layout program, a dedicated web server was installed for the survey pages by my colleague Juha Evokari from the SimLab research unit, and the answers were sent via e-mail to myself, using a cgi-script. Although once developed this technique worked excellently, I would advise anybody to use already existing software / web-based solutions if one does not happen to have an IT guru sitting in the next room. As soon as the survey was ready for use, it was tested by the usability laboratory of Helsinki University of Technology – a step that is highly recommendable. The test reduced the risk of unclear questions and resulted in a number of measures to decrease the time needed for answering the survey. Finally, before the survey was put online, the questionnaire was filled in by three pilot companies. Their feedback gave additional insight into "real business life" and resulted in four additional measurement items.

3.4.2 Choosing Potential Respondents - the Higher in the Hierarchy the Better?

In order not to let competitors recruit their specialists, the majority of companies do not provide any extensive contact lists on their websites. Usually, public companies list only the executive board members, and private companies are generous if they reveal who their CEO is. Anyhow, it is an illusion to think that very senior executives of large-size companies have enough time to participate in survey research. In these cases, it has proven useful to simply contact their assistants with the request to let the senior executive delegate the participation to a suitable person. This has the positive side effect that ones research is practically 'endorsed' by that executive.

3.4.3 Luring the Prey

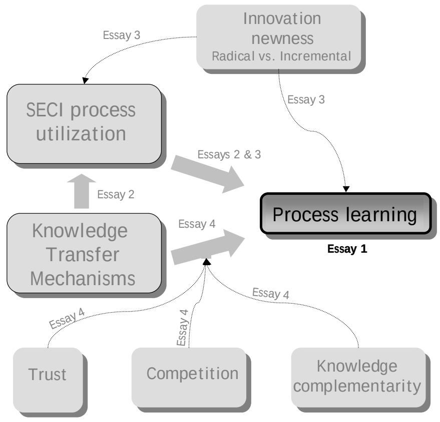
The key learning point of my survey research has been: phone the potential respondent before sending anything via traditional- or e-mail. If the person is too busy to take ones phone call even after the third try, he or she will be also too busy to fill in the questionnaire – resulting in a cascade of repeated calls and a variety of (mostly polite) excuses why the questionnaire has not been filled in yet. In all but two cases in this survey, a person that had not participated by the third follow-up call would not participate at all.

The advent of electronic voice dialing systems – especially in the UK and the USA – provide a clear advantage for a researcher trying to get past the numerous Cerberuses guarding the way to senior executives. While the majority of company staff – including switchboard assistants and secretaries – might still be on their way to work, those senior executives apparently tend to use the early morning hours to clear their work desk before the rumble of the day begins. These hours are the ideal time to attack – the target is no yet submersed into the daily working stress, and the voice dialing system will reliably connect one's call directly to their phone.

For following up, I strongly advise anybody to try to get the personal e-mail address of their contact. This makes following up very easy, as the problem of Cerberuses seems yet to be less present in the (under-)world of e-mails.

4 SUMMARY OF THE ESSAYS

4.1 *Outcomes of Process Learning in R&D Alliances – Results from Action Research in the Telecommunications Industry*

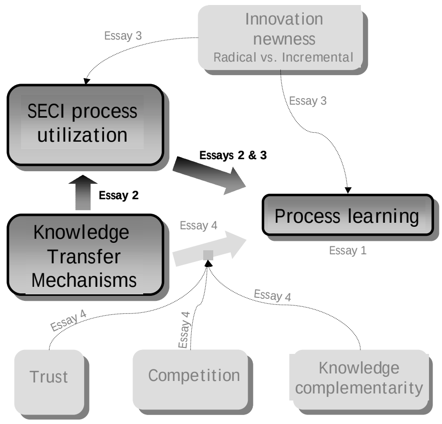


The first essay reports on the development of the set of process learning measures applied in this dissertation. As stated earlier, it is well known that measuring learning is highly challenging. Since previous literature did not provide satisfactory measures for the international survey that the remaining essays are based on, they needed to be developed. The set of measures is the result of a two-case study performed in the context of collaborative R&D in the telecommunications industry. The aim of this essay is to propose a measure for inter-partner process learning in collaborative R&D that – in contrast to previous research – directly measures the outcome of that learning: improved collaborative R&D processes.

The units of analysis were two collaborative R&D projects. The first project – conducted between a network equipment manufacturer and its supplier – was a three-year project during which a product for the business-to-business markets was developed. The second project – conducted between the network equipment manufacturer and a network operator – was a two-year advanced research project with the aim of gaining experience and new knowledge of a new mobile access technology. The data in both cases has been collected through interviews, business process simulations, and debriefing sessions. The findings were verified through follow-up interviews with the project managers.

The case companies came up with seven central process improvements during the research. The use of *joint project planning and evaluation meetings* was a major improvement in the companies' process. In these meetings, which are participated by both companies, members of a starting project meet members from previous collaborative projects, and jointly plan the starting project. In the same manner, the project is evaluated together with members of future collaborative projects. Improvements in the *prototyping process* were crucial especially since prototypes also act as showcases for the capabilities of the partner. Weaknesses in the prototyping were thus easily hampering / would thus easily hamper the overall relationship with the partner. Improvements in the *release management process* were another central learning point. Since the functionalities of each product release need to be known e.g. by the salesmen of the selling partner, the establishment of a joint release management plan was deemed an important improvement. A *joint process definition*, especially concerning *joint milestones*, was an improvement that occurred especially in the first case project, as did an improved, clear *division of tasks and responsibilities*. Increased *inter-departmental and cross-functional interaction* within each company was found to improve the collaborative R&D process through an improved knowledge-flow. Especially interactions between the R&D and marketing departments were crucial in order to keep up with changing customer requirements and market data.

4.2 How Companies Learn to Collaborate: Emergence of Improved Inter-organizational Process in R&D Alliances



In an inter-organizational R&D project, the collaborating partners accumulate shared knowledge on the product they develop, on the specific R&D project, as well as the generic R&D processes of their own and their partners. It is possible to distinguish between two inter-related processes of knowledge creation in collaborative R&D alliances. The primary knowledge creation process aims at developing new or improved products, whereas the secondary process involves learning about how to manage and implement R&D projects in inter-organizational settings.

The Nonaka & Takeuchi (1995) model of knowledge creation – presented in Figure 4 – has become widely accepted in a variety of management fields, such as organizational learning, joint ventures, new product development and information technology (Choi & Lee 2002; Kidd 1998; Nonaka et al. 2000). Although intuitively appealing, there is not much empirical evidence confirming this model. This essay sets out to test this model in the context of the secondary learning process mentioned above: inter-organizational process learning. Since the question of whether process learning follows this model has many managerial implications, the study is not limited to mere theory testing, but has also significance for the practitioner. The measure of process learning is a subset of the findings presented in essay 1. In the survey, the measure was rated by two independent members of each organization – a senior officer, and a project manager. The survey results verified the measure, since the inter-rater correlation analysis provided a significant and sufficiently high correlation between each pair of answers. In addition to this, the essay contributes to research by specifically mapping knowledge transfer mechanisms to each phase of the SECI model developed by Nonaka and Takeuchi.

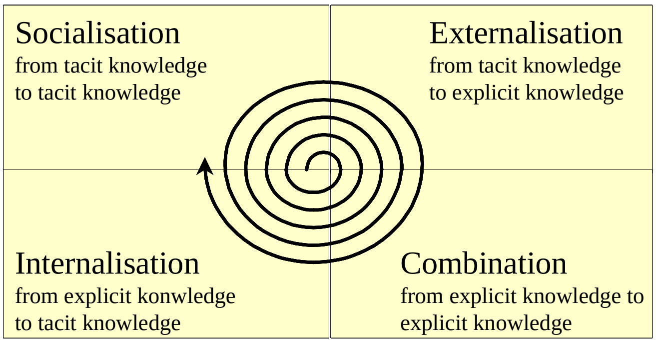


Figure 4: The SECI knowledge creation process Nonaka and Takeuchi 1995, 71, Nonaka, Toyama, Konno, 2000)

The Nonaka & Takeuchi model is based on the four knowledge creation processes socialization, externalization, combination and internalization. The main message of the model is that organizations need to experience the complete cycle of these knowledge creation processes before most of the learning and creation of new organizational knowledge possible takes place. Based on the model, and on previous research on communication in R&D collaboration, five main hypotheses were developed and tested with means of mediated multiple regression analysis.

Socialization encompasses the direct sharing of tacit knowledge between individuals and parts of the organization. Knowledge transfer mechanisms supporting this include for example in-depth teamwork and co-location. The direct transfer of tacit organizational knowledge, e.g. behavioral routines, leads to immediate improvements. Accordingly, the results of the study show that the use of knowledge transfer mechanisms for socialization is positively associated with process learning. It is also worthwhile noticing that other knowledge creation processes do not mediate the impact of socialization mechanisms.

Externalization – the conceptualization of experience, inner images, and ideas – is often challenging. In the context of collaborative R&D projects, externalization may take place in joint meetings (Smeds et al., 2001). In such meetings, knowledge about the collaborative R&D project and its management practices in partner organizations is explicated and conceptualized through dialogue. However, as with combination, for new collaborative R&D practices to emerge, it is required that this newly explicated knowledge becomes assimilated by individuals and groups. As the results show, this happens through internalization and socialization.

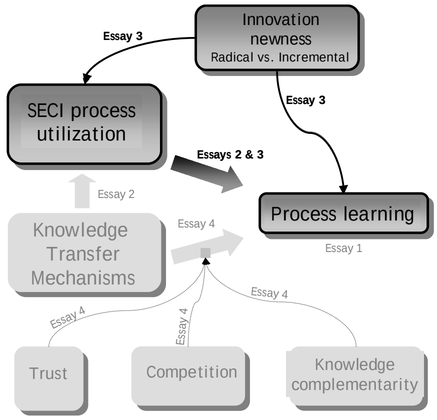
Combination refers to the process, where different, explicit knowledge items are combined to form new knowledge. As prior studies suggest, the best way to support the combination of explicit knowledge are collaborative environments utilizing information technology – in our case for example telephone conferencing and e-mail. However, the results show that the mere existence of new explicit knowledge does no mean that the organization or its individuals have learned anything yet. This explicit knowledge needs to be internalized into the organization's processes and tacit knowledge in order for learning to take place. This is especially important in the context of the strongly increased use of combination mechanisms such as e-mail and telephone conferencing: sharing knowledge through these only contributes to learning if the other three sectors of the SECI process are in place.

Internalization is the process through which individuals assimilate knowledge, i.e. explicit knowledge is converted into tacit knowledge. In the context of collaborative R&D projects with partners physically apart, internalization should be primarily supported by shared visual and written material directly applicable to distributed R&D work. Although an individual's internalized knowledge is crucial for the emergence of an improved capability to manage collaborative R&D processes, its impact is likely to remain limited unless shared with other individuals and groups. As the results show, this internalized, tacit knowledge can be spread in the organization in two ways: Externalization mechanisms – for example meetings –enable an individual to explicate the tacit knowledge acquired, and share this explicit knowledge with other members of the organization. On the other hand, as mentioned above, the tacit knowledge may also be shared directly through socialization.

Finally, the study set out to test, whether breaking the continuous socialization-explication-combination-internalization (SECI) -process influences the process learning outcome negatively. The firms were divided into groups that show a gap in the use of a specific knowledge creation process, and groups that do not show this gap. Among the respondent companies of the survey the only larger gaps that existed were in socialization and internalization. Here, the results show that companies that do not use socialization or internalization mechanisms learn less than companies going through the complete SECI process.

To conclude, the essay shows that the SECI process can be applied to inter-organizational learning. The findings imply that tacit knowledge is acquired by different knowledge transfer mechanisms than explicit knowledge. In order for an organization to maximize process learning in collaborative R&D, the communication between the partners needs to embrace mechanisms that support each of the four knowledge conversion processes of the SECI framework.

4.3 Process Learning in Alliances Developing Radical versus Incremental Innovations: Evidence from the Telecommunications Industry



This essay adds to the existing knowledge on alliance management by identifying distinct approaches to knowledge creation in R&D alliances, resulting in differences in the degree to which partners are able to upgrade their collaborative R&D processes. The purpose of the essay is to explore whether these differences can be attributed to various technology, company, product and relationship-specific characteristics. In addition to the process learning measure presented in the previous essays, this study uses a number of self-assessed perceptive learning measures. The results show that the alliances developing radical as opposed to incremental innovations differ from one another in terms of various partner-specific and alliance-specific characteristics as well as in their learning outcomes.

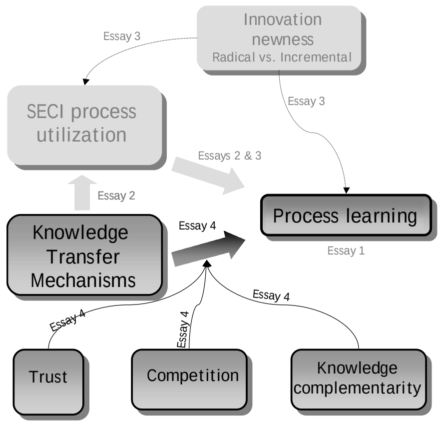
The data for this study is based on the international survey performed on 105 R&D partnerships worldwide. By means of cluster analysis, the companies were grouped according to their use of four knowledge creation processes in their inter-firm communication. These knowledge creation processes – socialization, externalization, combination and internalization – are based on the work of Nonaka et al. (1995). The cluster variate was created by grouping a number of specific knowledge transfer mechanisms used for communication according to these four knowledge creation processes. The cluster analysis resulted in three distinct clusters, which were then analyzed for differences in their characteristics and learning outcomes.

The first cluster was comprised of purely Scandinavian, experienced collaborators developing mainly incremental innovations. The cluster is comprised of large companies, with a median of employees at 625, and the lowest R&D intensity of the clusters. The members of this cluster were most active in utilizing all four knowledge creation processes, and most successful in process learning. The second cluster, medium-sized firms, was not specialized in a certain type of product, but developed both radical and incremental products. Nevertheless, the members of this cluster showed the highest R&D intensity. The cluster ranked in the middle in its use of knowledge creation processes, but nevertheless learned least collaboration skills from their partners. The last cluster consisted of small firms with only little collaboration experience developing radical innovations. The cluster showed the lowest degree of inter-partner control, and was mainly characterized by ad-hoc partnerships without previous partner-specific experience. It ranked lowest in use of knowledge creation processes, learning about the partner's R&D process and improving one's own collaborative process. Especially internalization was a weak spot in this cluster.

When comparing the clusters, the differences between companies developing incremental vs. radical innovations become obvious. The former firms tend to partner with familiar companies that they already have collaboration experience with. They have a higher learning motivation, their relationships are characterized by a higher degree of trust, they use knowledge creation processes the most, and these companies also learn more. The latter type of firms seems to be too busy with developing their radical innovation in order to engage in process learning. Even though they collaborate with unfamiliar partners – companies that generally carry more new knowledge to learn from than already familiar organizations – firms developing radical innovations do not use this chance. One explanation for this behavior might lie in the fact that the development process of a radical innovation is usually unique and needs not to be applied repetitively – thus there being less motivation for process learning.

The results show that alliances that differ in terms of the degree of innovativeness of the products developed also differ from each other significantly in various partner-specific and alliance-specific characteristics as well as in their process learning outcomes. Especially, the results suggest that companies which focus on incremental innovations seem to be more concerned with improving their collaborative R&D processes, and in the end also are the best learners. In contrast to this, companies that do not focus on either radical or incremental innovation but instead develop products of all degrees of innovativeness show the highest R&D intensity, but learn least collaboration skills from their partners. Finally, the study shows that companies mainly developing radically new products engage in process learning only very little.

4.4 The Influence of Inter-Partner Competition, Trust, and Knowledge Complementarity on the Effectiveness of Knowledge Transfer Mechanisms for Process Learning



The previous essays try to shed light on how inter-partner process learning takes place in different contexts. Using a more pragmatic approach, the last essay sets out to assess how the effectiveness of knowledge transfer mechanisms is affected by the relationship between the partnering companies. The statistical method used is moderated multiple regression analysis. In contrast to the previous essays, the knowledge transfer mechanisms were classified more straightforwardly and less theory-bound, namely by the medium used. The knowledge transfer mechanisms were grouped into three main groups: meetings, the transfer of people, and written documents.

Previous research on factors affecting the success of knowledge transfer has focused on three different areas: the nature of the knowledge to be transferred, the characteristics and behavior of sender and recipient, and the characteristics of the relationship between sender and recipient. Since the research focus of this essay lies in the nature of the specific relationship, the latter approach was chosen. Three prominent relationship characteristics were chosen for examination: the competitive situation, the existence of inter-organizational trust and the degree of complementarity between the organizational knowledge bases.

The *competitive situation* between the two collaborating companies undoubtedly influences the effectiveness of knowledge transfer mechanisms. Various studies have shown, that under competition, companies try to learn faster than their competitor, thus engaging in so-called learning races (Child 2001, Dussauge et al. 2000). Previous research has also shown a positive impact of competition on learning within the setting of inter-team or inter-business unit competition (Szarka et al. 2004). The results of this study support this view and show that competition has a significant, positive effect on the effectiveness of all three classes of knowledge transfer mechanisms: meetings, the transfer of people, and written documents. It is remarkable that the highest positive impact exists on the transfer of people.

In order to enable collaborating companies to learn from each other, the partners' *knowledge bases* need to *complement* each other (Cohen and Levinthal 1990, Sapienza et al., 2004). If the knowledge bases are completely similar, there is nothing to learn. The more complementary these knowledge bases are, the more knowledge there is to exchange. Since the focus is here on the *organizational* knowledge base and not on individual knowledge, the transfer mechanisms investigated here are the ones that act on the *organizational level,* namely meetings and written documents. As hypothesized and supported by the results, the complementarity of organizational knowledge bases positively influences these transfer mechanisms.

Behavioral trust relates to the expectations that a firm has concerning the non-opportunistic behavior of its partners. Most alliances try to reduce this risk by developing formal, often written, or informal "codes of conduct" to prevent other partners' opportunistic behavior. Written guidelines act as a safeguard for formalized knowledge transfer mechanisms that can be governed by formal codes of conduct – for example written documents and meetings with their written agendas and meeting minutes. Compared to the use of documents and formal meetings, it is relatively hard to formulate written agreements and rules on how knowledge flows through the transfer of people to the partner organization. As the results show, for the kind of informal exchange of knowledge that takes place through transfer of people, behavioral trust is the safeguard that gives the partners the secure feeling needed to freely share knowledge. However, the positive influence of behavioral trust diminishes as transfer of people is used more intensively.

To conclude, this essay demonstrates that competition, knowledge overlap, and trust within an R&D collaboration relationship do not affect all knowledge transfer mechanisms in the same way. Interestingly, the findings show that competition between two companies – once they decide to partner up for an R&D project – increases the effectiveness of knowledge transfer mechanisms and thus supports inter-partner process learning. Additionally, the study shows that trust has a positive effect on learning that takes place through the transfer of people between organizations. This effect is especially strong when the transfer of people is only used on a small scale. With an increased use of transfer of people, the positive effect of inter-partner trust diminishes.

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ESSAY 1: Outcomes of Process Learning in R&D Alliances – Results from Action Research in the Telecommunications Industry

This essay is based on research work to be published in a forthcoming article in "Production Planning and Control" (Feller et al., forthcoming)

1 Abstract

This essay reports the results of an exploratory action research study aiming at developing measures for process learning in R&D Alliances. Previous research usually measures process learning through the use of proxies, such as an improved productivity or innovativeness. These proxies measure improvements in the outcome of the organizational activity, which may, however, be dependent also on a number of other factors than successful process learning. This essay uses the improvements in the joint R&D process of partners to two R&D alliances to develop a set of measures for process learning. In contrast to the proxy measures used in previous research, the measures developed in this essay reflect better the characteristics of the R&D process itself, and are thus less influenced by external factors. The essay ulitizes methodological triangulation: Action research was conducted in two case companies (Feller et al., forthcoming) applying the business process simulation method as well as case interviews. The main results of this essay are distinct process improvements that the case companies have learned through their R&D collaboration.

2 Introduction

The rapid development and changes in the telecommunications industry have as a consequence that the ability of a company to continuously improve innovation capability and R&D processes is crucial for maintaining its competitive advantage. The accelerating time-based competition especially in the information- and communication technology (ICT) industry has changed the traditional in-house R&D processes and led to a rise in external acquisition of technology (Hauschildt 1992). The reduction of uncertainty, shortening of lead-times, increased flexibility, enhancing innovation inflow, scale benefits and cost reduction are basic motives for R&D alliances that have been identified by researchers (Bruce, M. et al. 1995, Hagedoorn, J., 1993). As external technology acquisition is more and more integrated into the product creation processes of enterprises, R&D performed in knowledge-based networks of companies can be seen to be the 5th generation of R&D (Rogers 1996).

R&D is nowadays often performed in a "Collaborative innovative system" that embodies learning across organizational boundaries (Rogers 1996). Next to knowledge about how to conduct collaborative R&D, this learning also encompasses knowledge on how organizations may conduct their internal R&D, on the technology and product they are developing, about new organizational forms (Smeds, R., 2000), about ways to generally cooperate in alliances (Cohen, W., and Levinthal, D. 1990) and more specific to cooperate with a certain partner (Lane, P. and Lubatkin, M., 1998). Process learning, which is defined as the successful transfer or creation and implementation of process-related knowledge, constitutes a central part of this cross-boundary learning, and is the focus of this essay.

Any endeavour to achieve and improve process learning in organizations is however dependent on a key issue: In order to be able to assess, whether an activity contributes to process learning, this learning needs to be measured. It is generally acknowledged that measuring learning is challenging (Argote 1999). Many studies attempt to measure successful process learning with the help of numerous proxies such as an increase in productivity, (e.g. Argote 1999, Arrow 1962), innovativeness (Tsai 2001), or even share price (Anand & Khanna, 2000). While all these factors are certainly affected by successful learning, they are also influenced by a number of other factors.

This essay develops a set of measures for process learning that is tied more closely to the R&D process itself. This is achieved by deriving a number of improvements that collaborating companies in two R&D alliances have jointly come up with through their collaborative effort. The research methods used in this action research are two: business process simulation, and case interviews. The action research was performed in 2000-2001, and was part of the three-year R&DNet research project, which was conducted jointly between the SimLab research unit at Helsinki University of Technology and three companies from the Finnish telecommunications industry. The following chapter provides an insight into the field of inter-organizational learning – which is naturally also the underlying concept of inter-partner process learning – with a special focus on the transferability of knowledge.

3 The Transferability of Knowledge: Tacit, Implicit vs. Explicit, Codified

Knowledge differs in the extent to which it is embedded into its surrounding context and transfer medium. The extent of this embeddedness is often referred to as codification or explicitness, vs. tacitness or implicitness of knowledge. Obviously, the more interconnected knowledge is with other knowledge and experiences of the individual carrying it, the higher the difficulty to transfer the knowledge to another person or a group of persons. Among the first researchers to investigate this issue was Polanyi (1966). His pioneering work on the tacitness of knowledge was developed further by, amongst others, Nonaka and Takeuchi (1995). In their work on organizational knowledge transfer in product development they coined the terms of tacit vs. explicit knowledge.

Explicit knowledge is formal, often in written form, objective and easy to express. Knowledge is tacit – or implicit – when it is highly dependent on the context of other knowledge, experience and wisdom of the person that carries the knowledge. Tacit knowledge can according to Nonaka et al. (2000) only be transferred through the creation of a shared context, wandering around, learning-by-doing and observing. The tacit-explicit classification of Nonaka and Takeuchi has been extended into three types by Maula (2000). According to her, explication of knowledge does not automatically lead to objectification and availability of that knowledge for others. Modern ICT technology such as the Internet provides huge amounts of explicit knowledge, which at least in part – e.g. in chats, personal web pages and digital photographs – is highly subjective. Second, even when knowledge is explicit, it is often unstructured and "chaotic", and available in magnitudes that escape the capacity of human brains, leading to what is known as information overflow. Accordingly, Maula proposes to extend this typology to tacit knowledge, less-structured knowledge (knowledge that contains unstructured personal elements such as e-mail communication) and highly structured knowledge. This view is shared by Bartezzaghi et al. (1997), who classify knowledge into tacit, explicit and codified knowledge, where codified knowledge is knowledge that is available in codified form such as written documents, but not easily accessible.

3.1 Inter-partner Tansfer of Process Knowledge Through Business Process Simulation

The inter-partner transfer of process-related knowledge was facilitated in the action research by applying business process simulation. This method has been used for process development, training, change management (Smeds and Alvesalo 2003, Forssén, Haho 2001, Haho, Smeds 1997), development of existing systems and re-engineering of business processes and operations (Savukoski et al. 1995). The method used in this study has been developed in Finland and has been successfully applied in other countries, and even in projects crossing different physical locations and cultures (Smeds and Alvesalo, 2003, Smeds, 1997). The use of business process simulation and its close relative, gaming, supports the change of paradigms and existing mental models and helps to create shared understanding among the participants (Tsuchiya and Tsuchiya 1999). Gaming and simulation can support organizations to achieve *voluntary learning, creation of a shared experience, the prerequisites to critically* *assess the validity of existing paradigms* and *a holistic view of the issue considered in the game* (ibid.). Process modelling, which is a central, part of the business process simulation method applied, provides among other things *greater visibility of the process, better identification of process weaknesses, clarification of responsibilities* and *identification of less well-understood processes* (Kawalek P, 1991). The method applied in this study creates a *process knowledge sharing and creation space*, a 'Ba' (Nonaka and Konno 1998), or a virtual *community of practice* (Wenger 1998), where the visual process map is simulated through *joint discussion* based on the attendants' experience and group context. Thus the method is especially applicable to business processes like R&D processes, in which the knowledge intensity and human communication are central (Hirvensalo et al. 2003). Business process simulation generates ideas for process improvement and thus creates – as soon as those ideas have been implemented successfully – business process innovations. (Hirvensalo et al. 2003, Smeds and Alvesalo 2003)

4 Case Study – process innovation in collaborative R&D

4.1 Method and Research Design

This paper is based on empirical research that has been carried out as an exploratory case study using action research methods, analysing two collaborative R&D projects. The study has been reported in detail in Feller et al. (forthcoming). During this action research, distinct process learning of the participating companies emerged as outcomes of the collaborative R&D efforts. Feller et al. (forthcoming) used two methods of data collection: business process simulation and case study interviews. In their study, business process simulation was used as a method for action research. The factors necessary for successful application of business process simulation as an action research method are, among others, suitable capabilities of the research team, a well-structured research plan and the comprehensiveness of the participants (Feller et al. forthcoming, see also: Smeds and Alvesalo 2003, Forssén and Haho 2001). The case study conducted by Feller et al. (forthcoming) includes a sufficient amount of data sources (over 60 participants), documents the sources intensively both during the simulation sessions and the case interviews, and the unit of analysis and the research method chosen are suitable for the purpose of the study. These characteristics of the research make the case study both reliable and valid (Yin 1994).

4.1.1 Research Question and Propositions of This Essay

The research question answered by this essay is the following:

> *"How can inter-partner process learning in collaborative R&D be measured in the form of concrete process improvements?"*

The exploratory nature of this question makes exact research propositions both unnecessary and impossible to state (Feller et al. forthcoming). However, a good research design demands a statement of purpose as well as success criteria for the study (Yin 1994). The purpose of this action research-based case study is to identify process learning that the case companies have come up with during their collaborative R&D effort. This study does not evaluate, whether these learnings lead to long-term superior process performance, but is merely concerned with generating a qualitative list of learning outcomes that can be applied and tested in empirical research to measure process learning.

4.1.2 Scope and Unit of Analysis

The scope of this study is the Finnish telecommunications industry. The units of analysis in are two collaborative R&D projects that have been carried out by altogether three different partner companies (Feller et al. forthcoming).

Case "Module"

The companies in the first project – "Module" – were a System Integrator (Beta) and a supplier company (Alpha). Alpha is specialized in contract design of electronic circuits and in providing data communication applications. Alpha mainly carries out R&D collaborations with companies that are located closer to the end-customer in the value chain. Their partner in this case, Beta, is a System Integrator, for whom the product was developed. The "Module" case project lasted three years, and the product developed was part of a larger entity sold by Beta in the business-to-business markets. The companies collaborated in a partnering mode, even though the relationship between the companies was a customer-supplier relationship. The project was carried out between summer 1998 and autumn 2000. Alpha's role in the collaboration was to develop the "case unit": *an indoor unit for microwave radio used in GSM networks*, sold exclusively by Beta. The project was characterized by intense collaboration especially in the hardware and software design functions. The collaboration between the partners was most intensive at the design stage of the project, as well as in system integration and quality tests in the end stage of the project. The initial requirement specification was carried out solely by Beta. The project assignment was then given to Alpha, who formed a project team to realize it. This team consisted of SW and HW designers led by a project manager. A coordinating project manager was also assigned from Beta's side.

Although the contract was written between Beta's (RT) Site and Alpha, several more interfaces were actively involved in the case project: First, Beta's marketing department co-ordinated the global sales and marketing efforts for the case indoor unit's product family. In the case project, the marketing department communicated with project management, submitting customer feedback and market forecasts. Second, since the case unit was part of a larger product family, its development was tied to other concurrent indoor unit projects in the RT division. Third, as a linkage between the outdoor unit and the base station, the case unit had to comply with the base station technology. Fourth, since Alpha did not manufacture the indoor unit hardware in-house, a manufacturing subcontractor formed the last communication interface. The project was conducted in a business arrangement where risks and rewards were shared. Beta's motivation for engaging into the project was a lack of resources to develop the product in-house.

Case "New Technology"

The second project included in this action research – "New Technology" – was a joint project of the System Integrator (Beta) and a Network Operator (Gamma). The project lasted roughly two years. The aim of this advanced research project was to gain insight into the use of a new mobile access technology. Beta had developed the new technology, which was still in the pre-commercialisation phase, and wished to collect information from the viewpoint of its' potential customers (Feller et al., forthcoming). The "New Technology" project can be divided into three project phases: test specifications, tests and analyses, and the presentation and documentation of results. The first phase consisted of a series of meetings between Gamma and Beta in which the joint tests were specified. The second project phase consisted of tests and test analyses. The third project phase did not include any meetings between the partners. The project was conducted via phone and e-mail discussions between project members. The partners documented the project and presented the project results internally. Gamma had a clearly defined project team, but Beta assigned only some project members to work full time on the project, whereas others worked for the project in an "ex-temporae" fashion when called in.

4.2 Data Collection

The data collection methods used in both cases included face-to-face interviews, business process simulations, debriefing workshops and follow-up interviews with the project managers, in which the findings were verified. The method of business process simulation is explained in the following sub-chapter, where also the reasons for using this research method are presented. The "Module" case project had about 50 project members, 25 of whom were interviewed by the research team, and 33 participated in the simulation session. Out of the 25 interviewed persons, 19 represented the System Integrator, 5 the Subcontractor, and 1 a third supplier. The data collection for this case was carried out during 8-11/2000. The "New Technology" case project included 25 members. Out of these, twelve persons were interviewed face-to-face by the research team, and ten participated in the process simulation (Feller et al. forthcoming). The data collection started with a one-hour phone interview in February 2001 from which the research team got its basic knowledge about the project. After this the overall objectives, steps, and schedule of the research were established in a common meeting between researchers and company representatives. After a month of preparations a group charting session was arranged in Gamma's facilities. The result, a rough project model, was used in the following 11 interviews as a basis to build on and to make the model more accurate. The project was simulated with four members from Beta and six members from Gamma, from which two were observers. Following the simulation the research team went through the development ideas and refined them into a document. This document was then evaluated with key persons from the companies in the debriefing session in June 2001.

4.2.1 SimLab Business Process Simulation

The business process simulation method used in this study as well as the reasons for its use have been introduced in chapter 3.1, and reported in detail in Feller et al. (forthcoming). The process steps for carrying out the simulation game are depicted in Figure 5.

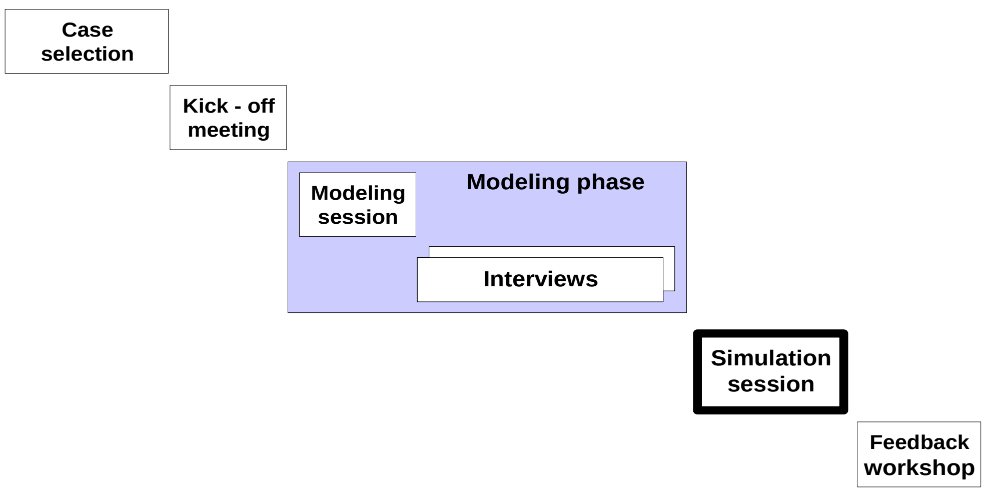

Figure 5: The business process simulation method as used in this study

After the kick-off meeting, where the needs of the partner companies and the research team were shared and explicated, the next step was the modeling session, were a crude project model was constructed. A group of 15 people plus the research team was involved in the session. The main objective was to reproduce the activities of the past project in a chronological sequence, and to find the most important interdependencies between the activities. A simple technique of hand-written paper notes was found most feasible. The flowchart created in this way was then transferred into electronic format. The example in Figure 6 has been rendered impossible to read due to confidentiality reasons.

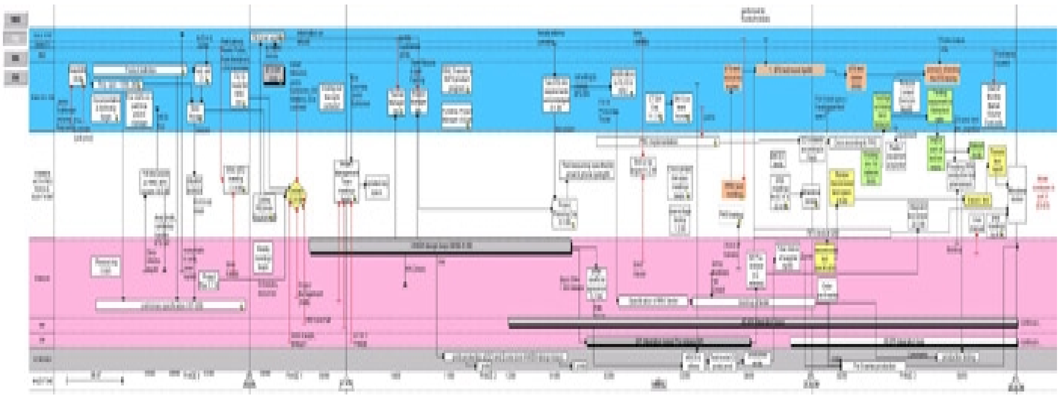

Figure 6: Process Flowchart, rendered illegible due to confidentiality reasons (Source: Feller and Hirvensalo, 2002)

After this phase, the flowchart models were completed based on face-to-face interviews with the members of the project team. After this modelling phase, process simulation sessions were arranged. For a further description of the process simulation method as well as the collection of improvement ideas, please see Feller et al. (forthcoming).

5 Results: Measures for Process Learning

The action research resulted in seven central process improvements, developed and adopted by the collaborating companies. These process improvements have been reported in Feller et al. (forthcoming). In the following, these process improvements are shortly introduced and then evaluated in the light of existing theory and of their applicability as a set of measures for process learning.

5.1 Improvements and Increase in Prototyping

Improvements in the use of prototypes were one of the learning outcomes, especially in the "Module" – case. These improvements relate to the use of a joint mode of prototyping, an increased use of prototypes, as well as the introduction of early, so-called "quick-and-dirty" prototypes into the collaborative R&D process. The use of rapid prototyping has been proven in different research settings to improve R&D processes, especially through increasing speed-to-market without negatively influencing quality (Lynn and Akgun 2003, Bernard et al. 2003). Additionally, a well-functioning prototyping has been stated to be a key characteristic of advanced R&D processes (Wheelwright & Clark 1992: 136). Previous research also stresses the necessity of embedding the prototyping process into the overall product development process in order to ensure the combination of the results of different design teams working in parallel (Roller et al. 2004). As collaborative R&D processes strongly face the need of combination of results even from different organizations, the improvement of prototyping seems to be a central and important outcome for inter-partner process learning.

5.2 Release Management

A second process learning outcome for the companies participating in the "Module" project was the use of a joint release management plan, in which the two parties specify beforehand, the functionalities included in each product release. Originally developed in the software industry, release management refers to the functionalities of different publicly released stages of the product (Ramakrishnan, 2004). Collaborative R&D projects, as they are often facing a large amount of interfaces between the partner organizations, require a well-planned release management (Feller et al. forthcoming).

5.3 Joint Milestones

The need for a joint definition of "milestones" or "stage-gates" for the collaborative project was a key finding in the "Module" project. The project started without a joint understanding on the contents of the key milestones, which lead to a delay of the project as both parties delivered different content for the first milestones (Feller et al. forthcoming). In previous research, joint milestone reviews have been found to act as one of the key integrators of cross-functional efforts in product development, while simultaneously posing a major challenge for many companies (Nihtilä 1999, Kunkel 1997).

5.4 Clear Division of Tasks and Responsibilities

The definition of clear responsibilities and the division of tasks was another major learning outcome in the "Module" case project, and a major success factor for the "New Technology" project. The positive impact of clear task division (or "partitioning") on the performance of distributed and even inter-firm projects has been introduced by von Hippel (1990), and since then specified especially in the context of the automotive industry (e.g. Dyer 1996).

5.5 Joint Meetings for Project Planning and Evaluation

An additional learning point was the launching of joint project planning and evaluation meetings, with participants from both the current project and previous projects. It was stated that even though project kick-off meetings and closing meetings are common, they seldom include members from other projects that could participate in the transfer of lessons learnt (Feller et al., forthcoming). Again, the existence of a joint planning meeting was deemed a major success factor for the "New Technology" project (ibid.). While numerous researchers stress the importance of evaluation meetings for the successful transfer of lessons learnt, there seems to be no previous empirical evidence on whether this practice contributes to the R&D process.

5.6 Learning Outcomes for the Intra-organizational Product Development Process: Inter-departmental and Cross-functional Interaction

Two additional learning points emerged from action research focusing on the internal R&D processes of the case companies. These improvements include inter-departmental- and cross-functional interaction[8]. Even though these issues had an impact on the collaborative R&D process, they cannot be considered as process learnings concerning this collaborative process, since they relate to the internal R&D processes of the partner companies.

6 Discussion

The main process learning outcomes for the collaborative process of the case companies are five direct process improvements: an *increased and improved use of prototyping,* improvements in *release management,* a *joint process definition and joint milestones,* clear *task division and definition of responsibilities,* and the introduction of *joint project planning and evaluation meetings*.

Of these collaborative R&D process improvements, the management of prototypes, definition of milestones and clear allocation of tasks and responsibilities are key characteristics of advanced R&D processes and the main determinants of time to market (e.g. Wheelwright & Clark 1992: 136). These three items are confirmed by previous research (Bernard et al. 2003, von Hippel 1990, Kunkel 1997, Lynn and Akgun 2003, Nihtilä 1999, Wheelwright and Clark 1992), and are therefore included in the process learning construct used in the following essays.

A novel item derived from the case study was improved release management. Deemed of utmost importance in rapidly evolving high-tech industries, it has nevertheless not been

[8] see Feller et al. 2004 for more information on these findings

researched in the context of (collaborative) R&D. This managerial practice originating from the software industry synchronizes the rapid clock speed of launching new product releases to the market with the slower pace of marketing and customer relationship management. In collaborative R&D projects, synchronizing the introduction of new product releases and their marketing is highly important, but also very hard to achieve.

The use of project planning and evaluation meetings was a novel finding in this study. However, these meetings take place outside of the actual collaborative R&D project itself – either before or after the project. Due to this reason they are not considered improvements of the actual collaborative R&D process, and – while being important parts of R&D collaboration management in general – are thus not included in the construct. Through the same reasoning increases in inter-departmental and cross-functional interaction are left outside the construct.

The development of concrete measures from the findings of this study can be done by following one of two alternative routes. First, the findings can be directly used to create self-assessed measures. Second, the findings can be used further to create a number of objective, quantitative measurement items for each of the findings. While leaving the latter route for further research, I propose the following self-assessed measure for process learning occurring through a collaborative R&D project to be derived from the findings of this study.

Table 2: Measurement Items for the Process Learning Measure

Items
The project helped us to improve our use of prototypes in collaborative projects.
The project helped us to improve our release management in collaborative R&D projects
Through the project, we learned to better divide tasks & responsibilities in collaborative R&D projects
The project has improved our use of milestones in collaborative projects

The proposed measure consists of four measurement items that are to be rated on a seven-point Likert scale, and are displayed in Table 2.

7 Limitations and Future Research

The main limitations of the underlying action research used are elaborated on in Feller et al. (forthcoming). The main weakness of the process learning measure proposed is the self-reported character of the measure, making it easily susceptible to common method bias or ex-post rationalisation. In order to tackle this weakness, the use of multiple independent raters from each organization is strongly advised.

The findings of this study open an avenue for further research to develop quantitative, non-self-assessed measures for each of the findings. These measures should allow for an objective assessment of process learning. The self-assessed process learning measure proposed in this study is used within an international survey in the quantitative research reported in the following essays. The three following essays of this dissertation present the results of this research.

8 Acknowledgements

This study has been part of the R&D Net research project carried out at the SimLab research unit at Helsinki University of Technology. The aim of this multidisciplinary project was to study the developing and managing of networked R&D process innovations in the telecommunications industry. The research was guided by Professor Riitta Smeds, head of SimLab and the R&D Net project, and Professor Hannele Wallenius, Dr. Annaleena Parhankangas and Dr. Thomas Keil, from the Institute of Strategy and International Business at Helsinki University of Technology. I am grateful for the joint research effort of the whole project team and the valuable guidance of the supervisors, which have made this work possible. The research is financially supported by the Finnish Technology Development Centre Tekes and the case companies, which is gratefully acknowledged.

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ESSAY 2: How Companies Learn to Collaborate: Emergence of Improved Inter-organizational Process in R&D Alliances

This essay has been presented at the Strategic Management Society's Conference 2004

1 ABSTRACT

Our paper seeks to establish a link between the implementation of four knowledge conversion processes - socialization, externalization, combination and internalization- and an improved capability to manage inter-organizational R&D processes. Relying on the data from 105 R&D partnerships in the global telecommunications industry, our study suggest that weaknesses in any of these knowledge conversion processes have the potential to hamper the proper functioning of the other knowledge conversion processes, and thus, overall process learning.

2 Introduction

The only sustainable competitive advantage for companies in turbulent industries stems from their innovative capability. To keep up with competition, companies need to create new or improved product offerings with high speed, flexibility and reliability. Continuous upgrading of R&D processes has thus emerged as primary target for many organizations as they are starting to extend the application of process management philosophy from initial manufacturing applications to new product development processes (Benner & Tushman, 2002; Harry & Schroeder, 2000; Repenning & Sterman, 2002).

Inter-firm collaboration may help companies face the challenge of continuous renewal. Various studies suggest that inter-firm collaboration spurs innovativeness of the organizations involved (see, for instance, Cohen & Levinthal, 1990; Goes & Park, 1997; Hagedoorn, 1993; Lee, Lee, & Pennings 2001; Teece, 1987). Despite their upside, R&D alliances are complex organizational forms, involving tacit, non-routine and highly uncertain knowledge conversion processes fraught with ambiguity (Anand & Khanna, 2000; Winter, 1988).

Prior research maintains that the capacity to manage alliances is a distinct capability, defined as the ability to identify, negotiate, manage, monitor and terminate collaborations (see, for instance, Anand & Khanna, 2000; Draulans, DeMan & Volberda, 2003; Kale, Dyer, & Singh, 2002, 1998; Simonin, 1997; Zollo, Reuer & Singh, 2002;). This body of literature assumes that firms will be more successful in their alliances, when they continuously develop mechanisms and routines to accumulate, store, integrate and diffuse relevant knowledge related to the management of alliances (Anand & Khanna, 2000; Dyer & Singh, 1998; Inpken & Dinur, 1998; Kale et al., 2002). Prior research has identified several dimensions of alliance capability, such as the existence of a dedicated alliance function (Kale et al, 2002); partner-specific, technology-specific, and general experience accumulation (Zollo et al., 2002); as well as relation-specific assets, knowledge-sharing routines, complementary resources, and effective governance (Dyer & Singh, 1998).

Our paper focuses on an important, but hitherto neglected aspect of alliance capability, by investigating how partnering firms may learn how to better manage their collaborative R&D processes. In particular, we seek to establish a link between the implementation of four knowledge conversion processes - socialization, externalization, combination and internalization- and an improved capability to manage inter-organizational R&D processes. The theoretical foundation of our work relies on the Nonaka and Takeuchi (1995) model of organizational knowledge creation. The empirical data is based on a survey on 105 R&D partnerships in the global telecommunications industry. In our study, R&D alliances are defined as formal or informal partnerships [9] with the aim of developing a new product or technology to be used by one or both of the partners, or adopting a new technology for future use.

The Nonaka & Takeuchi (1995) model of knowledge creation has become widely accepted in a variety of management fields, such as organizational learning, joint ventures, new product development and information technology (Choi & Lee, 2002; Kidd, 1998; Nonaka, Toyama, & Nagata, 2000). Although intuitively appealing, there is not much empirical evidence confirming this model. One of the notable of exceptions is the study by Kidd (1998) of knowledge creation in Japanese-Italian production subsidiaries in Italy. He suggests that the contextual aspects may govern knowledge creation in joint venture subsidiaries and concludes that "success" is due to the blending of contextual factors so as to ameliorate the intercultural conflicts that may easily arise in the overseas ventures. Sabherwal & Becerra-Fernandez (2003) and Nonaka et al. (2000b) have investigated how internalization, externalization, socialization, and combination contribute to perceived individual-level, group-level, and organizational-level knowledge management effectiveness and overall performance. To our knowledge, our study is the first effort to test the Nonaka and

[9] These partnerships may include equity alliances or more informal forms of collaborative relationships.

Takeuchi model of knowledge creation in inter-organizational processes in general and collaborative R&D settings in particular.

3 Theoretical Context: The Nonaka & Takeuchi Model of Dynamic Knowledge Creation

The literature on organizational learning is vast, drawing on multiple disciplines and theoretical perspectives (for a review, see for instance Dodgson, 1993; Easterby-Smith, 1997; Shrivastava, 1983). In this study, collaborative R&D processes are understood as inter-organizational learning systems. We focus on process learning, i.e. improvements in the practices of collaborative R&D, as they are conceived in the R&D process of the collaborating organization. Because of our interest, we chose to rely on particular streams of literature, maintaining that knowing and learning are collective accomplishments residing in the networks of relationships between organizations and subjective experiences of individuals and groups (Araujo, 1998; Boland & Tenkasi, 1995; Venzin, Von Krogh & Roos, 1998) or, put differently, situated within the communities of practice (Lave & Wenger, 1991; Wenger; 1998). Besides viewing learning as social phenomenon, we are interested in how new knowledge is created in inter-organizational partnerships. Nonaka & Takeuchi (1995) model of knowledge conversion seems to integrate the two aspects of social learning and distributed knowledge creation and thus became the theoretical lenses, through which we analyze knowledge creation in R&D alliances. This model was originally developed to analyze the development of product innovations, but it can also be applied to process innovations and learning (Smeds 1997).

The Nonaka & Takeuchi (1995) model is based on knowledge conversions that relies on Polanyi's (1958) distinction between explicit and tacit knowledge. Explicit knowledge can be expressed in words or numbers and shared in the form of data, scientific formulae, specifications and manuals. According to Spender (1996), tacit knowledge can be best described as knowledge that has not yet been abstracted from practice. It is deeply rooted in an individual's actions and experience as well as in his or her ideals, values, and emotions. Tacit knowledge may also be held collectively in shared collaborative experiences and interpretations of events, firm routines and firm culture (Nelson & Winter 1982; Nonaka & Takeuchi, 1995; Nonaka, 1994; Polanyi, 1958). Thus, tacit knowledge is highly personal and hard to formalize, communicate or share with others.

According to the dynamic theory of organizational knowledge creation, knowledge creation is a spiraling process of interactions between tacit and explicit knowledge, where tacit knowledge is shared, explicated, and combined into new knowledge through joint human experience and communication (Leonard & Sensiper, 1998; Nonaka, 1994; Nonaka & Takeuchi, 1995). This learning spiral relies on the four modes of knowledge conversion: socialization, externalization, combination and internalization, as shown in Figure 1.

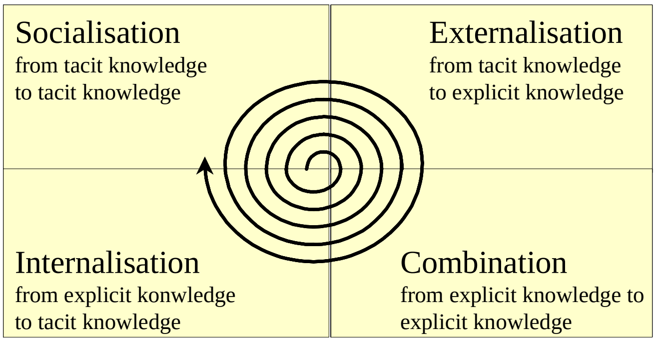

Figure 7: The process of dynamic knowledge creation (Nonaka and Takeuchi 1995: 71)

Socialization plays a crucial role in the knowledge creation spiral. In human interaction, individual experiences, mental models and skills are shared collectively to become 'sympathized' tacit knowledge. Externalization of this tacit knowledge into explicit, conceptual knowledge is triggered through dialogue between individuals and groups. This explicit knowledge is then combined with knowledge from other parts of the organization, crystallizing it into new systemic knowledge. Finally, the new systemic knowledge is internalized through learning by doing. Interaction with others may again facilitate sharing this knowledge through socialization, which starts a new spiral of knowledge creation. An underlying idea of this spiral consists of the assumption that organizational knowledge creation starts at the individual level, and moves up through communities that interact with each other, crossing sectional, departmental, divisional and organizational boundaries. (Nonaka, 1994; Nonaka & Takeuchi, 1995: 70-71; Nonaka et al. 2000b).

4 Socialization, Externalization, Combination, Internalization and the Improved Capability to Manage Collaborative R&D Processes

In an inter-organizational R&D project, the collaborating partners accumulate shared knowledge on the product they develop, on the specific R&D project, as well as the more generic R&D processes of their own and their partners. It is possible to distinguish between two inter-related processes of knowledge creation in collaborative R&D alliances. The primary knowledge creation process aims at developing new or improved products or production processes, whereas the secondary spiral involves learning about how to manage and implement R&D projects in inter-organizational settings. If successful, the secondary spiral generates practical new knowledge and experience, spurring improvements in day-to-day collaborative R&D practices of the parties involved and benefiting future collaboration projects (Smeds, Olivari & Corso, 2001). In this study, we focus on the secondary spiral of R&D process learning by investigating the role of socialization, externalization, combination and internalization in the emergence of improved collaborative practices in the context of inter-organizational R&D projects.

Socialization involves the sharing of tacit knowledge through joint activities, such as spending time together, living or working in the same environment and relating to others (Nonaka, Toyama, & Konno, 2000). Through socialization, individual experiences, mental models and skills are shared collectively to become 'sympathized' tacit knowledge*,* deeply embedded in emotions and nuanced contexts that are associated with the shared experience (Nonaka & Takeuchi, 1995). Knowledge transfer mechanisms supporting socialization include co-location, team work, coaching, corridor talk, apprenticeship, use of mentors, and job rotation (e.g. Smeds et al., 2001). In collaborative R&D settings, face-to-face-interaction may facilitate forming a "common ground" or "shared understanding" on beneficial ways to collaborate. As this tacit knowledge is disseminated further through socialization, improvements in the collaborative R&D processes are likely to follow. Therefore, we assume that

Hypothesis 1. Socialization is positively associated with an improved capability to manage collaborative R&D processes.

Through internalization, individuals assimilate knowledge, i.e. they convert explicit knowledge into tacit knowledge. Internalization is thus a prerequisite for successful learning on the individual level. Internalization may happen through learning by doing in real life situations, simulations, or through observation (Nonaka & Konno, 1998; Nonaka & Takeuchi, 1995). Knowledge transfer mechanisms such as training programs with senior mentors, on-the-job training, visual process maps, "best practices" workshops, or exercises can be used to support internalization (Nonaka et al., 2000a, Smeds et al., 2001). In the context of collaborative R&D projects with partners physically apart, we expect that internalization is primarily supported by shared visual and written material directly applicable to distributed R&D work.

Although an individual's internalized knowledge is crucial for the emergence of an improved capability to manage collaborative R&D processes, its impact is likely to remain limited unless shared with other individuals and groups. To contribute to learning on the organizational level, individual learning has to move up through communities that interact with each other, crossing sectional, departmental, divisional and organizational boundaries (Pautzke, 1989; Wenger, 1998). This requires both externalization and socialization. Externalization mechanisms, such as meetings, are instrumental for explicating the knowledge of an individual for the use of others through dialogue. In a similar vein, socialization mechanisms such as corridor talk, coaching and job rotation may help transferring tacit knowledge from one individual to another. Therefore,

Hypothesis 2. Internalization is positively associated with an improved capability to manage collaborative R&D processes.

Hypothesis 2a. The effect of internalization on an improved capability to manage collaborative R&D processes is partially mediated by socialization.

Hypothesis 2b. The effect of internalization on an improved capability to manage collaborative R&D processes is partially mediated by externalization.

Combination creates new systemic, explicit knowledge by combining diverse items of explicit knowledge. In practice, the combination phase involves three processes: i) capturing and combining explicit knowledge from inside and outside the organization; ii) disseminating the new explicit knowledge to others; and iii) editing or processing the combined explicit knowledge items into plans, reports, documents, or market data, or electronic data bases. According to prior studies, the combination of explicit knowledge is best supported by collaborative environments utilizing information technology, for instance, e-mail and telephone conferencing (Nonaka & Takeuchi, 1995; Nonaka & Konno, 1998; Nonaka et al., 2000a). However, it is highly unlikely that combination alone results in improved collaborative R&D practices. In order for this new combined explicit knowledge to lead to an improved capability to manage collaborative R&D processes, it has to be internalized into tacit individual knowledge, such as behavioral routines and practices. Therefore we hypothesize that

Hypothesis 3. The effect of combination on an improved capability to manage collaborative R&D processes is fully mediated by internalization.

Externalization of tacit knowledge and its translation into forms easily conveyed to others may prove to be challenging. It is often difficult to conceptualize experience, inner images, and ideas. Externalization often requires a certain amount of trust or a shared feeling of belonging to a group. Externalization may be supported by the use of metaphors, narratives, visual images, and concepts, which help creating a joint language and a fruitful dialogue (Nonaka & Takeuchi, 1995; Nonaka & Konno, 1998; Nonaka et al., 2000a).

In the context of collaborative R&D projects, externalization may take place in joint meetings (Smeds et al., 2001). In such meetings, knowledge about the collaborative R&D project and its management practices in partner organizations is explicated and conceptualized through dialogue. This facilitates decision-making, the division of tasks and the definition of R&D procedures, as well as supports the learning of new collaborative practices. However, we do not believe that the mere explication of tacit knowledge is enough to lead to improved collaborative R&D practices. For new collaborative R&D practices to emerge, it is required that this newly explicated knowledge becomes assimilated by individuals and groups. This is likely to happen through internalization and socialization. Therefore, we hypothesize

Hypothesis 4a. The effect of externalization on an improved capability to manage collaborative R&D processes is partly mediated by internalization.

Hypothesis 4b. The effect of externalization on an improved capability to manage collaborative R&D processes is partly mediated by socialization.

As explained above, companies and individuals within them need to go through the spiral of socialization, externalization, combination and internalization processes in order to learn new collaborative R&D practices (Nonaka, 1994; Nonaka & Takeuchi, 1995; Nonaka et al., 2000a,b). Weaknesses in any of these knowledge conversion processes may hamper the implementation of the other processes, thus potentially jeopardizing overall learning. For instance, organizations ignoring socialization and internalization practices may end up with huge amounts of explicated knowledge stored in reports, databases, and presentations. Unfortunately, none of this knowledge is likely to transform into improved R&D practices (Nelson & Winter, 1982). In addition, weaknesses in socialization, externalization and combination practices may lead to situations, where the learning of an individual is never transformed into the learning of an organization (Nonaka, 1994). Thus, we hypothesize that

Hypothesis 5a. A gap in socialization is negatively associated with an improved capability to manage collaborative R&D processes.

Hypothesis 5b. A gap in externalization is negatively associated with an improved capability to manage collaborative R&D processes.

Hypothesis 5c. A gap in combination is negatively associated with an improved capability to manage collaborative R&D processes.

Hypothesis 5d. A gap in internalization is negatively associated with an improved capability to manage collaborative R&D processes.

Based on prior literature, we decided to control for several factors possibly affecting the nature and outcome of collaborative R&D alliances. First, the existence of competition between alliance partners is likely to influence their collaborative behavior and thus, inter-company learning (Larsson, Bengtsson, Henriksson, & Sparks, 1998; Tsai, 2002). Second, the degree to which the partners will be able to learn from each other depends on the similarity and complementarity of their knowledge bases (see, for instance, Cohen & Levinthal 1990; Lane & Lubatkin 1998; Sapienza, Parhankangas & Autio, 2004). Third, the quality of current and past collaboration relationships is an important determinant of inter-organizational learning (Kale et al., 2002; Lane & Lubatkin, 1998). Fourth, the motivation behind the R&D alliance (Dussauge, Garrette, & Mitchell, 2000; Hennart, 1988) and the existence of a jointly defined R&D process (Hirvensalo, Evokari, Feller, Pekkola, Turunen, & Smeds, 2003) are likely to affect process learning outcomes. Finally, we decided to control for some basic characteristics of the participants, such as their R&D intensity and size.

5 Method

5.1 Data Collection

The data for this study was gathered through an international survey conducted during the years 2002-2003. Our questionnaire was developed based on prior literature on strategic alliances and two case studies conducted within the R&D Net project at the SimLab research unit of Helsinki University of Technology. The case studies were explorative in nature, analyzing inter-partner learning in two collaborative R&D projects within the Finnish telecommunication industry. The data collection for case studies involved interviews, business process simulations (cf. Smeds & Alvesalo 2003), debriefing sessions and follow-up interviews with the project managers for verification of the findings (for a more detailed description of the case studies, please see Feller et al., forthcoming, and Hirvensalo et al., 2003). We used the case studies mainly for gaining a better understanding of knowledge conversion processes in R&D alliances and developing our dependent variable, the improved capability to manage collaborative R&D processes.

The targeted population in our survey was the network operators, network equipment manufacturers, and suppliers to network equipment manufacturers in the telecommunications industry in Europe, Northern America and Asia. The sample companies were identified by using company directories, industry associations and trade fair exhibitor catalogues. [10]

Before sent out, our questionnaire was tested both by the employees of the pilot companies [11] and the usability laboratory of Helsinki University of Technology. Data collection started with two rounds of mailings to 517 companies in 72 countries. This resulted in only 20 responses. To increase our response rate, the questionnaire was posted on the Internet. By accessing new databases, we were able to add 126 new companies from Finland, Germany, the UK and the US to the sample. We contacted all potential respondents by phone, after which we sent them an e-mail message containing the link to the survey and some additional instructions. The second round produced the majority of the responses from 85 firms.

In order to increase the quality of the data, the questionnaire was divided into two parts, to be answered by two individuals. The first part focusing on company-level questions was filled in by the Vice President of R&D or the Chief Technology Officer of the respondent company. After filling in the first part, the respondent was asked to choose a collaborative case project and to forward the second, project-specific part of the questionnaire to the project manager of the case project. The case project had to fulfill the following criteria: First, the project involved developing a new product or technology to be used by one or both of the partners, or adopting a new technology for future use. Second, the product or technology developed within the project had to be telecommunications-specific. Third, the project had to involve some interaction between the technical staff of the partnering firms, as opposed to being a mere outsourcing project. Fourth, the project had to be completed by the time the questionnaire was filled in.

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[10] The online sources used were Hoover's Online (www.hoovers.com), Europages (www.europages.com), the Applegate Directories (www.applegate.co.uk), Kellysearch (www.kellysearch.com), Global Sources (www.globalsources.com), Vendora (www.komponentit.com), Yahoo (www.yahoo.com), Yritystele (www.yritystele.fi), Inoa (www.inoa.fi), The GSM association (www.gsmworld.com), UMTS Forum (www.umts.org), CeBit Trade Fair (www.cebit.de), GSM World Congress http://www.gsmworldcongress.com).

[11] The pilot companies include the companies from the previous case studies .

5.2 Sample

Out of the total population of 643 companies, 28 companies reported that the survey did not apply to them (either they had no R&D or R&D collaboration, or they were not in the telecommunications industry). These companies were eliminated from the sample, leaving us with a targeted sample of 615 companies. Out of the targeted sample of 615 companies, we received 105 responses, resulting in a response rate of 17,1%.

Most of our sample companies were network operators (12,6 %), network equipment manufacturers (42,7 %), and suppliers to network equipment manufacturers (41,7%). In addition, a few companies were active in the area of mobile terminals. In terms of size, most of the respondents were relatively small companies, with annual sales of less than 50 Million USD and fewer than 100 employees. The respondents were located mainly in Finland (35), the UK (22), the US (13) and Germany (10). All in all, we received replies from 19 countries. Besides our sample being mainly composed of European firms, there seems to be no other significant differences between the respondents and non-respondents, for instance, in terms of the size of the company.[12] Finally, we found no differences between the early and late respondents, or responses delivered through a paper or Internet questionnaire.

5.3 Constructs

Independent Variables

Prior literature suggests that it possible to operationalize highly intangible *knowledge conversion processes* by using various knowledge transfer mechanisms as a proxy (Nonaka & Takeuchi, 1995; Nonaka et al., 2000a; Sabherwal & Becerra-Fernandez, 2003). We derived the knowledge transfer mechanisms from the study of Smeds et al. (2001) focusing on R&D collaboration in the ICT industry. Following the example of prior literature, the knowledge transfer mechanisms were classified according to the four knowledge conversion processes (Nonaka & Takechi, 1995; Sabherwal & Becerra-Fernandez, 2003). The underlying idea behind this classification is that a particular knowledge transfer mechanism is mainly used to facilitate one of the knowledge conversion processes, even though it may play a minor role in supporting other knowledge conversion processes in R&D alliances.

[12] Data on non-respondents was retrieved from company Internet sites.

This classification of knowledge transfer mechanisms based on socialization, externalization, combination and internalization was confirmed by the means of factor analysis (see Table 1). For each of these knowledge transfer mechanisms, the project manager was asked to indicate on a scale from 1 to 7 how frequently a particular knowledge transfer mechanism was used between the partners to an R&D alliance. The four factor solution explained 46-68 percent of the total variance

Table 3: Operationalization of Knowledge Conversion Processes

Variable	Measurement Item	Factor Loading
Socialization (α = .76)	Co-location	.653
	Coaching	.681
	Job Rotation	.845
	Process Consultants	.821
Externalization (α=.88)	Design Review Meetings	.870
	Test Specification Meetings	.729
	Test Result Review Meetings	.880
	Prototype Review Meetings	.819
	Milestone Review Meetings	.825
Combination (α= .75)	E-mail	.872
	E-mail distribution lists	.743
	Telephone conferencing	.653
	Progress reports (during the project)	.717
	Project Documentation	.655
	Written Process Descriptions	.626
Internalization (α=.80)	Lessons learnt presentations	.699
	Lessons learnt reports	.812
	Visual process maps	.762
	Final customer reports	.680
	Final reports	.795

Knowledge transfer mechanisms supporting *socialization*, or in other words, transferring tacit knowledge, include face-to-face interaction, joint activities and spending time together, rather than giving or receiving written and verbal instructions (Nadler, Thompson, & Van Boven, 2003; Nonaka & Takeuchi, 1995; Nonaka & Konno, 1998). In R&D partnerships, companies sometimes co-locate some of their employees at their partner company (e.g. Hirvensalo et al., 2003; Sabherval & Becerra-Fernandez, 2003). Among other purposes, co-location may facilitate transferring tacit knowledge from the more experienced company to the less experienced partner. This knowledge transfer may take place through coaching, job rotation or the use of process consultants. In addition, co-location may allow the team members to engage in informal corridor talk, during which experiences and other tacit knowledge may be exchanged (Hirvensalo et al., 2003).

Externalization often requires that an individual feels being part of the group in order to feel comfortable enough to convert his or her tacit knowledge into a form easily understandable to others (Nonaka & Konno, 1998; Nonaka et al., 2000a). In R&D alliances with team members coming from different organizations, the "team spirit" needs to explicitly created. Various meetings may serve as occasions bringing team members together and providing a possibility for the explication of tacit knowledge on the collaborative R&D project and its management practices. [13] Based on Smeds et al. (2001), the most widely used meetings include design review, test specification, test results review, prototype review and milestone review meetings.

Combination involves gathering, combining, disseminating, editing and storing of explicit knowledge. It is characterized by collective, often virtual interaction (Nonaka & Konno, 1998, Nonaka & Takeuchi, 2000). According to Smeds et al. (2001), the most frequently used means for combination in R&D alliances include the use of e-mail, e-mail distribution lists and telephone conferences. In addition, new knowledge created through combination of existing explicit knowledge is often stored in written process descriptions, project documentation, progress reports and other knowledge repositories (Nonaka & Konno 1998; Sabherval & Becerra-Fernandez, 2003).

According to prior literature focusing mainly on knowledge conversion processes within single organizations, *internalization* involves the transformation of explicit knowledge into the tacit knowledge through learning by doing, simulation, observation and training (Nonaka & Konno, 1998; Sabherval & Becerra-Fernandez, 2003). R&D alliances, however, will provide fewer possibilities for these kinds of activities due to the tacit and abstract nature of R&D work and for the reason that partners are located physically apart. Therefore, we assume that individuals operating in inter-firm settings mainly resort to studying final reports and listening to presentations, when trying to assimilate explicit knowledge on collaborative R&D practices. In R&D projects, the most critical presentations and reports include lessons learnt presentations and reports, visual process maps, final reports and final customer reports (Smeds et al. 2001).

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[13] Tacit knowledge can also be at least partially externalized through the creation of documents or visual materials. However, the creation of documents and visual material was considered to be too time-consuming relative to the communication needs of new product development processes in fast-changing environments. This is the reason why we assume that meetings are the major means of externalization in R&D alliances.

Dependent Variable

The measure for the *improved capability to manage collaborative R&D processes* was developed based on a multiple case study reported in Feller et al. (forthcoming) and Wheelwright & Clark (1992). This study identified several improvements in collaborative R&D processes of alliance partners. These improvements may be interpreted as improved capability to manage collaborative R&D processes. These improvements include the introduction of joint project planning and evaluation meetings, improved use of prototyping - especially the use of intermediate prototypes-, improvements in release management, joint milestones, as well as clear allocation of tasks and responsibilities.

Of these collaborative R&D process improvements listed above, the management of prototypes, definition of milestones and clear allocation of tasks and responsibilities are key characteristics of advanced R&D processes and the main determinants of time to market (e.g. Wheelwright & Clark 1992: 136). These three items were therefore included in the construct. A novel item derived from our case study was improved release management, deemed of utmost importance in rapidly evolving high-tech industries, such as the telecommunications. This managerial practice originating from the software industry synchronizes the rapid clock speed of launching new product releases to the market with the slower pace of marketing and customer relationship management. In collaborative R&D projects, synchronizing the introduction of new product releases and their marketing is highly important, but also very hard to achieve.

These four items were rated by both the senior technology manager and the project manager on a seven-point Likert scale, see Table 2. For each item, the intra-class correlation coefficient was calculated. As all the ICC scores were above 0.65 ($p<0.01$) (Boyer & Verma 2000; Boyer & Lewis 2002), we were able to form a combined measure using the data from both respondents.[14] The factor analysis shows that all four items load on one factor. The Cronbach-alpha of this construct was .77, while the factor analysis explains 60% of the total variance.

14 For those cases for which only one answer was available, this answer was used.

Table 4: Operationalization of Independent and Control Variables [a]

Variable	Items	Factor Loadings
Improved Capability to Manage R&D Alliances	1. The project helped us to improve our use of prototypes in collaborative projects	.64
	2. The project helped us to improve our release management in collaborative R&D projects	.79
	3. Through the project, we learned to better allocate tasks and responsibilities in collaborative R&D projects	.79
	4. The project has improved our use of milestones in collaborative projects	.87
Perceived Competitive Situation	5. In some markets, we are in direct competition with our partner	.85
	6. We sell products that can substitute some of our partner's products.	.88
	7. At some point in the future, our partner could become our competitor.	.82
Knowledge Similarity	8. The technical knowledge and skills of our partner were very similar to our company's knowledge and skills.	.88
	9. The R&D management capabilities of our partner were very similar to us.	.83
Knowledge Complementarity	10. Our company and our partner complemented each other's technical knowledge.	.90
	11. Our company and our partner complemented each other's R&D management capabilities.	.85
Earlier Cooperation Experience	12. Our company's project members had extensive earlier cooperation experience with our partner.	.93
	13. Our partner's project members had extensive earlier cooperation experience with our company.	.85
	14. The project members from both sides have worked previously with each other.	.91
Inter-Organizational Trust	15. The project was characterized by mutual trust between us and the partner at multiple organizational levels.	.87
	16. Our partner has the reputation of being a reliable cooperation partner.	87

[a] In factor analyses, the principal component analysis is applied.

Control Variables

The questionnaire items measuring the *perceived competitive situation* between the respondent organization and its partner are self-developed and rated by the project manager on a seven-point Likert scale. Table 2 shows questionnaire items and factor loadings for this construct. The Cronbach alpha for the three items was 0.79, indicating a sufficient level of internal consistency. The factor analysis explained 71% of the total variance.

The questionnaire items measuring *knowledge overlap* have been developed based on prior literature (Davis, Robinson, Pearce & Park, 1992; Sapienza et al., 2004; Sorrentino & Williams, 1995). They were rated by the project manager on a seven-point likert scale. A factor analysis produced two factors, labeled as *knowledge similarity* and *knowledge complementarity,* see Table 2. The factor analysis explained 77 percent of the total variance. The Cronbach-alphas for knowledge complementarity and knowledge similarity were 0.65 and 0.71, respectively.

Prior collaboration facilitates communication through the emergence of informal ties and trust between the collaborating partners (Doz, 1994; Larson, 1992; Ring & Van de Ven, 1994). Companies with a long history of prior collaboration may also have developed so-called relative absorptive capacity facilitating learning from each other (Lane & Lubatkin, 1998). This construct was operationalized with three self-developed questionnaire items addressed to the project manager. The Cronbach-alpha was .88 and the factor analysis explained 81 percent of the total variance. For measurement items and factor loadings, please refer to Table 2.

Inter-organizational trust relates to the expectations concerning the non-opportunistic behavior of the alliance partner, or, as Kale at al. (2002) put it, the "confidence the partners have in the reliability and integrity of each other". In other words, the construct refers to mutual trust, respect and friendship within a relationship. The existence of trust has a twofold effect: on one hand, it facilitates learning by improving the information flow between the partners; on the other hand, it minimizes the risk of opportunistic behavior within an alliance. Table 2 presents the questionnaire items addressed to the project manager and factor loadings for the Inter-Organization Trust – construct. The factor analysis explains 75 percent of the total variance. The Cronbach alpha for items representing inter-organizational trust was 0.67, respectively.

The alliance partners' *motivation to learn from collaborative R&D projects* and the *existence of a jointly defined R&D process* were measured on a seven-point Likert scale with single questionnaire items. The motivation to learn from collaborative R&D projects in general was rated by the senior technology manager in charge of the overall alliance portfolio of the company. The existence of jointly defined R&D process was rated by the project manager in charge of the particular collaborative R&D alliance at the focus of our study.

6 Results

6.1 Tests of Hypotheses 1-4

In order to test the Hypotheses 1-4, we constructed a regression model with improved capability to manage collaborative R&D processes as dependent variable. Our independent variables include the four knowledge conversion processes described above. In addition, we controlled for some characteristics of the R&D alliance and the collaborating partners, such as motivation for the alliance, earlier collaboration experience, existence of a jointly defined R&D process, inter-partner trust, as well as the similarity and complementarity of the knowledge bases of the two partners.

To detect potential multicollinearity problems, we calculated intercorrelations among independent, dependent and control variables. As shown in Table 3, the intercorrelations among the four knowledge conversion processes are relatively high. The tolerance measures are nevertheless well above the critical threshold of 0,1 suggested by Hair, Anderson, Tatham & Black (1992). The highest intercorrelations between the independent variables can be found between externalization and combination. However, the models including those variables (models 1 and 5) display a tolerance measure above of 0,34.

Hypothesis 1 states that socialization is positively associated with an improved capability to manage collaborative R&D processes. The regression model 1 with all variables included (Table 4) seems to confirm this hypothesis. Socialization has a positive, statistically significant relationship with the dependent variable ($p<0,05$).

Hypothesis 2 suggests that internalization is positively associated with an improved capability to manage collaborative R&D processes. Model 1 shows no support for Hypothesis 2. We suspect that the impact of internalization might be veiled by the inter-correlations between the four knowledge conversion processes. Model 7 seems to confirm our beliefs: when socialization, externalization, and combination are removed, our results reveal a positive and statistically significant relationship between internalization and the improved capability to manage collaborative R&D processes. Hypothesis 2 thus receives partial support by our data.

Hypotheses 2a and 2b suggest that internalization is mediated by socialization and externalization, respectively. A mediating effect is present, if the following three criteria are fulfilled (Baron & Kenny, 1986): There has to be a significant relationship between the independent and the dependent variable. Second, the independent variable must be significantly correlated with the mediator. As Table 3 indicates, there exist significant correlations between all four knowledge conversion mechanisms. Thus, the second requirement is fulfilled for all hypotheses. Finally, the previously significant relationship between the independent and the dependent variable must be reduced, when the mediator is entered into the regression model.

Table 4 : Correlations, means and standard deviations

	Variables	Mean	s.d.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1.	Improved capability to manage collaborative R&D processes	4,48	1,14													
2.	Aim to learn about partners R&D processes	4,82	1,60	0,36												
3.	Net Sales, mUSD	834,84	4429,36	-0,34	-0,24											
4.	R&D/Sales ratio	0,31	0,34	0,28	0,19	-0,12										
5.	Joint R&D process for this project	3,64	1,92	0,35	0,25	-0,09	0,00									
6.	Earlier cooperation experience	3,87	2,04	0,25	0,18	-0,13	-0,07	0,31								
7.	Interorganizational Trust	5,24	1,24	0,32	0,16	0,02	0,10	0,32	0,31							
8.	Knowledge complementarity	5,21	1,31	0,12	0,01	0,11	0,06	0,16	0,01	0,18						
9.	Knowledge similarity	4,04	1,61	0,18	0,04	-0,03	0,08	0,27	0,23	0,19	0,25					
10.	Percieved competition	2,65	1,73	0,15	-0,08	0,02	-0,13	0,16	0,04	0,00	0,31	0,11				
11.	Combination	4,73	1,20	0,27	0,01	0,15	0,11	0,17	-0,08	0,29	0,33	0,19	0,11			
12.	Externalization	4,67	1,51	0,47	0,17	0,07	0,28	0,39	0,15	0,41	0,29	0,25	0,01	0,70		
13.	Internalization	2,86	1,43	0,42	0,26	0,03	0,06	0,27	0,21	0,31	0,17	0,20	0,07	0,60	0,51	
14.	Socialization	3,05	1,31	0,54	0,17	-0,23	0,19	0,25	0,36	0,31	0,14	0,21	0,05	0,35	0,41	0,42

Correlations greater than 0,20 are significant at $p < 0,05$; correlations greater than 0,28 are significant at $p < 0,01$; correlations greater than 0,35 are significant at $p < 0,001$

Table 5 : Test of hypotheses 1-4

Variables		Model								
		1	2	3	4	5	6	7	8	9
Control	Motivation to learn from partners' R&D processes	0,13	0,19^{+}	0,14	0,16	0,12	0,17^{+}	0,12	0,13	0,17^{+}
	R&D/Sales ratio	0,11	0,20^{+}	0,20*	0,18^{+}	0,14	0,13	0,21*	0,15	0,11
	Net Sales, mUSD	-0,24*	-0,29*	-0,29*	-0,23*	-0,31**	-0,30**	-0,29*	-0,31**	-0,24*
	Existence of a joint R&D process	0,05	0,13	0,12	0,12	0,05	0,06	0,13	0,06	0,07
	Earlier cooperation experience	-0,03	0,12	0,08	0,00	0,05	0,82	0,06	0,07	0,01
	Interorganizational Trust	0,07	0,13	0,13	0,10	0,09	0,10	0,14	0,09	0,08
	Knowledge complementarity	-0,04	-0,04	-0,02	-0,02	-0,04	-0,05	-0,01	-0,05	-0,05
	Knowledge similarity	-0,01	0,01	0,00	-0,01	-0,01	0,00	0,01	-0,01	-0,01
	Perceived competition	0,17^{+}	0,15	0,15	0,15	0,18^{+}	0,18^{+}	0,15	0,17^{+}	0,17^{+}
Independent	Externalization	0,30^{+}				0,36*	0,36**		0,27*	0,27*
	Internalization	0,17		0,23+	0,18	0,22^{+}		0,29*	0,19^{+}	
	Socialization	0,27*			0,28*					0,28*
	Combination	-0,14	0,24*	0,10	0,26	-0,10				
Regression	Adjusted R^2	0,37	0,28	0,30	0,35	0,33	0,33	0,31	0,35	0,38
	F	3,35***	3,02**	3,00**	3,27**	3,12**	3,54**	3,32**	3,44**	3,89***

Dependent Variable: Improved Capability to Manage Collaborative R&D Processes

$^{+}$ $p<0,1$ *$p<0,05$ **$p<0,01$ ***$p<0,001$

To test Hypotheses 2a and 2b, we first confirmed a significant relationship between internalization and the improved capability to manage collaborative R&D processes (model 3). Then we entered socialization into the regression model (model 4). The new model shows a slightly improved R^2 of 0.36. Socialization (the mediator) has a positive, statistically significant relationship with the dependent variable, while the effect of internalization becomes less significant in its presence (compare to model 7). In a similar vein, externalization has a positive, statistically significant relationship with the dependent variable (model 5), reducing the impact of internalization (compare to model 7). Thus, Hypotheses 2a and 2b are supported.

Hypothesis 3 suggests that combination is fully mediated by internalization. As shown in model 2, there is a positive, statistically significant relationship between combination and the improved capability to manage collaborative R&D processes. Next, we entered internalization, into the regression analysis (model 3). As a result, there is a positive, statistically significant relationship between internalization and the dependent variable, while the relationship between combination and the dependent variable no longer exists. Thus, Hypothesis 3 is supported.

Hypotheses 4a and 4b state that externalization is partially mediated by internalization and socialization, respectively. Externalization has a positive, statistically significant relationship with the dependent variable (model 6). When internalization is entered to the equation, the significance of this relationship is reduced (model 8). This suggests that externalization is partially mediated by internalization. In a similar vein, we were able to confirm that externalization is also partially mediated by socialization (model 9). Thus, Hypotheses 4a and 4b are supported. It is important to note that model 1 shows that externalization also exerts a direct impact on the dependent variable, a relationship not hypothesized in this study.

6.2 Test of Hypothesis 5

In order to test Hypothesis 5, we divided our sample into two groups based on the extent to which they use knowledge transfer mechanisms facilitating socialization, externalization, combination and externalization. The first group consisted of companies stating that they use very little or no knowledge transfer mechanisms related to a particular knowledge conversion process (on a scale from 1 to 7, replies with a mean of 2 or below). The second group consisted of firms using these mechanisms at least to some extent (replies with a mean of above 2).

When running the analyses, we found that 18 firms have a gap in socialization. In addition, it became evident that only six companies in our sample had a gap in externalization, and no company had a gap in combination. In a similar vein, a gap in internalization correlated significantly with the lower use of externalization (p<0,001), combination (p< 0,001) and socialization (p<0,1). In other words, companies using no internalization mechanisms tended also to use less externalization, combination and socialization mechanisms. We believe that this result as such already gives strong support to Hypothesis 5, stating that weaknesses in one of the knowledge conversion processes tend to hamper the proper functioning of other knowledge conversion processes, and thus process learning.

As a result, we were only able to test Hypothesis 5a and 5d predicting an adverse relationship between gaps in socialization and internalization, and an improved capability to manage collaborative R&D processes. [15] The comparison of means reveals that those companies with weaknesses in socialization practices are also worse-off in terms of learning to better manage their collaborative R&D processes (see Table 5). These two groups do not differ significantly in their use of other knowledge conversion processes. The only significant difference between the two groups is that companies weak in socialization practices have less often defined a joint R&D process with their partner. Hypothesis 5a was thus supported.

Table 7: Test of hypothesis 5

		Gap in Socialization		Gap in Internalization	
		Yes	No	Yes	No
		N=18	N=49	N=22	N=45
Knowledge Transfer Mechanisms used	Socialization[a,e]	1,5***	3,58***	2,54*	3,29*
	Externalization	4,43[e,c]	4,83[e,c]	3,86***,[d]	5,06***,[d]
	Combination[d]	4,63	4,79	4,03***	5,07***
	Internalization[e]	2,73	2,95	1,37***	3,6***
Control Variables	R&D Intensity (R&D/Sales)[e]	28,50 %	31,00 %	28,20 %	31,39 %
	Employees (median)[b,e]	102,00	80,00	40*	105*
	Net Sales (median), mUSD[e]	9,75	10,00	3,5*	13*
	Had a joint R&D process for this project[e]	3,00**	3,90**	2,64**	4,02**
	Aim to learn about partners R&D process in all collaborative projects[e]	5,01	4,88	4,32	5,02
Dependent variable	Improved capability to manage collaborative R&D processes	3,70*,[e]	4,60*,[e]	3,91**,[d]	4,68**,[d]

[a] Transformed to nat. logarithm before testing [b] Transformed to reciprocal sqrt before testing [c] Transformed to square before testing
[d] ANOVA [e] Mann-Whitney U test

We also compared the groups with and without a gap in internalization processes. Our results suggest that a gap in internalization practices is negatively associated with the improved capability to manage R&D alliances. These two groups also differ in terms of their use of socialization, externalization and combination practices as well as in terms of net sales and the number of employees. Our data thus gives weak support to Hypothesis 5d.

15 Since the statistical tests used are not robust against heteroskedasdicity (White 1980), some of the variables were transformed (see Table 5).

7 Discussion

Our study proposes that companies may learn to better manage their collaborative R&D processes through successful implementation of the four knowledge conversion processes: socialization, externalization, combination and internalization. To our knowledge, this study is the first one to empirically test the Nonaka & Takeuchi (1995) model of dynamic knowledge creation in inter-organizational settings in general and collaborative R&D projects in particular. Second, this study adds to the growing body of literature on strategic alliances, by focusing on a hitherto largely neglected aspect of alliance capability, i.e. the emergence of inter-organizational routines in R&D collaborations or knowledge management processes in alliances. Third, our study contributes to the process management literature by suggesting that R&D processes may be improved through facilitating the knowledge conversion processes between individuals and groups, as well as between tacit and explicit knowledge.

Our study provides strong support for the Nonaka & Takeuchi (1995) model of dynamic knowledge creation outside of the initial realm of Japanese culture. Due to numerous interactions between socialization, externalization, combination and internalization, it seems likely that weaknesses in any of these knowledge conversion processes have the potential to hamper overall learning. Interestingly enough, our results reveal that weaknesses in socialization mechanisms may be the Achilles' heel of many R&D partnerships and thus warrant the full attention of alliance managers in the future. This is hardly surprising given difficulties associated with transferring tacit knowledge (Leonard & Sensiper, 1998; Madhavan & Grover, 1998; Nonaka & Konno, 1998; Polanyi, 1958;) and the nature of distributed R&D work, where permanent co-location of collaborating partners is not always an option. As the results show, the use of mechanisms for socialization has a direct impact on the learning outcome. This implies that managers interested in achieving process learning should especially focus on the use of co-location, coaching, job rotation and process consultants for communication between the partners. By doing so they support the essential transfer of tacit knowledge between the partners – knowledge that encompasses deep-rooted experiences, expertise and insights, that are often extremely valuable and that can only be learned directly from other people.

The results also challenge the widespread use of mechanisms for combination such as e-mail-lists, telephone conferences or progress reports, if used without any supporting mechanisms from the other three SECI sectors. A project that relies solely on combination mechanisms, will significantly fall short of its learning potential. The main supporting mechanisms here are those fostering internalization, namely lessons learnt efforts and visual process maps. By providing the project members with those mechanisms – and the sufficient time to utilize them – a project manager will ensure that the knowledge created in this specific project will be spread and internalized allover the organization.

Contrary to our expectations, empirical evidence suggests that externalization may have a direct impact on the improved capability to manage collaborative R&D processes, even without the hypothesized mediating effects of socialization and internalization. We suspect that this may arise partly because of the difficulties in the operationalization of complicated and highly abstract knowledge conversion processes.

Our results seem to converge with an emerging stream of literature suggesting that it might be possible to manage and model R&D processes, despite their chaotic and unpredictable nature (Leifer, McDermott, O'Connor, Peters, Rice, & Verzyer, 2000; Repenning & Sterman, 2002). Moreover, our study gives reason to believe that this process learning may also be extended to inter-organizational R&D processes. This far, alliances have mainly been regarded as a gateway to new technologies, markets, and products, while less attention has been paid to the emergence of inter-organizational routines as one of their major benefits to the collaborating partners. Finally, the results show that the development of alliance capability includes a joint effort between collaborating companies, and that projects to develop this capability fall short of the optimum, unless they encompass collaboration with the partner organization.

8 Limitations and Avenues for Future Research

This study is subject to a number of limitations. First, it has been argued that knowledge creation processes are highly sensitive to the pervasive effect of culture (see, for instance, Glisby & Holden, 2003; Holden, 2001). Thus, a future study is required to explore the emergence of collaborative routines in alliances outside the geographical scope of our sample, i.e. outside Northern Europe and the United States. Second, our theoretical framework leaves much room for interpretation relative to the operationalization of the four knowledge conversion processes. It is possible that particular knowledge transfer mechanisms are mainly used to facilitate one of the knowledge conversion processes, as assumed in prior literature (Nonaka et al. 2000a; Sabherwal & Becerra-Fernandez, 2003) and our study. However, these same mechanisms may also play a minor role in supporting the other knowledge conversion processes. As a result, the operationalization of knowledge conversion processes might require more complex procedures than undertaken in prior literature and this study. In addition, several authors have questioned the way in which Nonaka and Takeuchi (1995) distinguish between explicit and tacit knowledge, regarding it as artificial or even misleading (Araujo, 1998; Inpken & Dinur, 1998; O'Donnell et al., 2000;

Tsoukas, 1996). Third, the link between improvements in collaborative R&D practices and innovativeness of an organization was beyond the scope of our study. Thus, a future research project could explore, for instance, how the standardization of collaborative R&D processes affects the emergence of radical, as opposed to incremental innovations (Benner & Tushman, 2002; 2003). Fourth, the scope of the study is limited to the telecommunications industry in general, and to R&D collaboration between network equipment manufacturers, their suppliers, and network operators in particular. This may weaken the applicability of our findings in other industrial sectors. Finally, an interesting avenue for future research would be investigating the emergence and evolution of collaborative R&D practices over time in a longitudinal research setting.

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ESSAY 3: Process Learning in Alliances Developing Radical versus Incremental Innovations: Evidence from the Telecommunications Industry

A previous version of this essay has been presented at the Continuous Innovation Network's Conference 2004, and was awarded the John Bessant Best Paper Award 2004.

1 Abstract

The aim of this study is to identify distinct approaches to knowledge creation in R&D alliances, and to link these approaches to differences in inter-organizational process learning in partnering firms. Our study is based on a survey of 105 companies in the global telecommunications industry. It seems that alliance partners developing incremental innovations use more extensively various knowledge transfer mechanisms than firms developing radical innovations. In addition, our results suggest that companies developing incremental innovations, companies with extensive cooperation experience with their partner, and companies with a higher overall use of knowledge transfer mechanisms will be able to learn and improve their collaborative R&D processes more than others.

2 Introduction

Prior research maintains that the capacity to manage alliances is a distinct capability, defined as the ability to identify, negotiate, manage, monitor and terminate collaborations (see, for instance, Simonin, 1997; Kale, Dyer, and Singh, 2002; Zollo, Reuer & Singh, 2002; Draulans, DeMan & Volberda, 2003; Dyer & Singh, 1998). Several dimensions of alliance capability have been indentified, such as the existence of a dedicated alliance function (Kale et al, 2002); partner-specific, technology-specific, and general experience accumulation (Zollo et al., 2002); as well as relation-specific assets, knowledge-sharing routines, complementary resources, and effective governance (Dyer & Singh, 1998).

Our paper adds to the existing knowledge on alliance management by identifying distinct approaches to knowledge creation in R&D alliances, resulting in differences in the degree to which partners are able to upgrade their collaborative R&D processes. Furthermore, we explore whether these differences can be attributed to various company, product and relationship-specific characteristics. The theoretical foundation of our study relies on the Nonaka and Takeuchi (1995) model of organizational knowledge creation. In our study, R&D alliances are defined as formal or informal partnerships [16] with the aim of developing a new product or technology to be used by one or both of the partners, or adopting a new technology for future use.

3 Theoretical Background

In this study, collaborative R&D processes are understood as inter-organizational learning systems. We focus on process learning, i.e. improvements in the practices of collaborative R&D, as they are conceived in the R&D process of the collaborating organization. Our focus leads to streams of literature that view knowing and learning as collective accomplishments residing in the networks of relationships between organizations and individuals (Araujo, 1998) or, put differently, situated within the communities of practice (Lave & Wenger, 1991). Besides viewing learning as a social phenomenon, we are interested in how new knowledge is created in inter-organizational partnerships. The Nonaka and Takeuchi (1995) model of knowledge conversion integrates the two aspects of social learning and distributed knowledge creation. It thus became the theoretical lens, through which we analyze knowledge creation in R&D alliances. This model was originally developed to analyze the development of product innovations in organizations, but it can also be applied to process innovations and learning (Smeds, 1997).

The Nonaka and Takeuchi (1995) model is based on knowledge conversions between explicit and tacit knowledge. Explicit knowledge can be expressed in words or numbers and shared in the form of data, scientific formulae, specifications and manuals. Tacit knowledge, in its turn, is not easily visible or expressible. It is deeply rooted in an individual's actions and experience as well as in his or her ideals, values, and emotions. According to Nonaka & Konno (1998), knowledge creation is a spiralling process of interactions between tacit and explicit knowledge, where tacit knowledge is shared, explicated, and combined into new knowledge through joint human experience and communication (Nonaka & Takeuchi, 1995; Leonard & Sensiper, 1998). This learning spiral relies on the four modes of knowledge conversion: socialization, externalization, combination and internalization, as shown in Figure 8.

[16] These partnerships may include equity alliances or more informal forms of collaborative relationships.

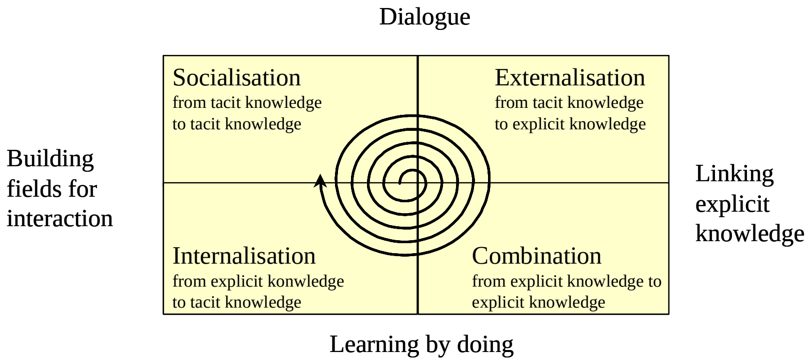

Figure 8. The SECI knowledge creation process Nonaka and Takeuchi 1995, 71, Nonaka, Toyama, Konno, 2000)

Socialization starts the knowledge creation spiral. In human interaction, individual experiences, mental models and skills are shared collectively to become 'sympathized' tacit knowledge. Externalization of this tacit knowledge into explicit, conceptual knowledge is triggered through dialogue. This explicit knowledge is then combined with knowledge from other parts of the organization, crystallizing it into new systemic knowledge. Finally, the new systemic knowledge is internalized through learning by doing. Interaction with others may again facilitate sharing this knowledge through socialization, which starts a new spiral of knowledge creation. In other words, organizational knowledge creation starts at the individual level, and moves up through communities that interact with each other, crossing sectional, departmental, divisional and organizational boundaries. (Nonaka and Takeuchi 1995, 70-71). The model has become widely accepted in a variety of management fields, such as organizational learning, joint ventures, new product development and information technology (Kidd, 1998; Nonaka et al., 2000, Choi & Lee, 2002). Although intuitively appealing, there is not much empirical evidence related to this model. The purpose of this paper is to extend the model by investigating whether different companies have adopted different approaches in the use of the four knowledge creation processes in their alliances, and if so, whether these differences can be explained by various company, product and relationship-specific characteristics.

4 Method

4.1 Cluster Analysis

We deployed cluster analysis to explore the potential differences in the use of knowledge conversion mechanisms in R&D alliances. The primary purpose of cluster analysis is to group objects based on the characteristics they possess and objectively reduce information from an entire population to the information about specific, smaller subgroups (Hair et al., 1995; Ketchen & Shook, 1996; Romesburg, 1984). However, cluster analysis may lead to misleading results if not carried out with great care. Most importantly, the researcher's definition of the cluster variate, or a set of variables used to compare objects, is a critical step in cluster analysis. Cluster analysis is the only multivariate technique that does not estimate the variate empirically but uses instead the variate defined by the researcher. Therefore, the definition of the cluster variate should be based upon careful theoretical or empirical considerations. In addition, cluster analysis requires several methodological choices that determine the quality of a cluster solution.

The cluster variate - i.e. the use of knowledge transfer mechanisms supporting socialization, externalization, combination and internalization – was derived from prior literature (Nonaka and Takeuchi, 1995). We have a reason to believe that these knowledge transfer mechanisms are representative of communication practices within the R&D function in general and inter-unit or inter-company R&D projects in particular (Smeds et al 2001). As depicted below, the cluster solution was profiled on additional information on the characteristics of partnering firms, characteristics of alliances and products being developed. It is important to note that we did not use these variables for clustering R&D alliances. Instead, we used these variables to "double-check" the quality of our findings and to interpret the results.

The major statistical concerns in cluster analysis are the representativeness of the sample and multicollinearity. As described more in detail below, the sample selection was done with great care. The use of telephone interviews made it possible to check that all the firms in the sample met the sampling criteria. This is an advantage difficult to achieve when relying solely on databases. Multicollinearity among the variables included in the variate may blur the results of the cluster analysis (Green, 1978). Correlation analyses show that the correlation coefficients between the clustering variables are well below the multicollinearity threshold of 0.7.

For the cluster analysis, the K-means cluster procedure was used to classify firms. Three clusters emerged from the statistical analysis, characterized by high, medium and low levels of use of all four knowledge conversion processes. The three-cluster solution provides theoretical and conceptual clarity by producing three distinct clusters with greatest inter-cluster differences, thus adding to our understanding of the use of knowledge transfer mechanisms in R&D alliances. We took an additional step to eliminate some of the concerns related to the fact that the results of a cluster analysis may be sensitive to clustering methods and algorithms used. We deployed a two-stage procedure recommended by experts (Ketchen & Shook, 1996; Hair et alii.,1995) to validate our cluster solution. In this procedure, an additional hierarchical analysis was performed. The cluster sizes and mean values of the clustering variate derived from the K-means cluster method and Complete linkage method are very similar, thus increasing the quality of our findings.[17]

4.2 Data Collection

The data for this study was gathered through an international survey conducted during the years 2002-2003. The questionnaire was developed based on the prior literature on strategic alliances and two case studies conducted within the R&D Net project at the SimLab research unit of Helsinki University of Technology. These case studies were explorative in nature, analyzing inter-partner learning in two collaborative R&D projects within the Finnish telecommunication industry. The data collection for case studies involved interviews, business process simulations (Smeds 2000, Smeds & Alvesalo 2003), debriefing sessions and follow-up interviews with the project managers for verification of the findings (for a more detailed description of the case studies, please see Hirvensalo et al., 2003 and Feller et al., forthcoming). The case studies were mainly used to gain a better understanding of the use of knowledge conversion processes and learning in R&D alliances and for developing one of our dependent variables focusing on improvements in collaborative R&D processes introduced by the partnering firms. Our questionnaire was addressed to network operators, network equipment manufacturers, and suppliers to network equipment manufacturers in the telecommunications industry in Europe, Northern America and Asia. The sample companies were identified by using company directories, industry associations and trade fair exhibitor catalogues[18].

Before sent out, the questionnaire was tested both by the employees of the case research companies and the usability laboratory of Helsinki University of Technology. Data collection started with two rounds of mailings to 517 companies in 72 countries. This resulted in only 20 responses. To increase our response rate, the questionnaire was posted on the Internet. By accessing new databases, we were able to add 126 new companies from Finland, Germany, the UK and the USA to the sample. We contacted all potential respondents by phone, after which we sent them an e-mail message containing the link to the survey and some additional instructions. The second round produced the majority of the responses, altogether from 85 companies.

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[17] The results of Complete linkage method will be made available upon a request from the authors.

[18] The online sources used were Hoover's Online (www.hoovers.com), Europages (www.europages.com), the Applegate Directories (www.applegate.co.uk), Kellysearch (www.kellysearch.com), Global Sources (www.globalsources.com), Vendora (www.komponentit.com), Yahoo (www.yahoo.com), Yritystele (www.yritystele.fi), Inoa (www.inoa.fi), The GSM association (www.gsmworld.com), UMTS Forum (www.umts.org), CeBit Trade Fair (www.cebit.de), GSM World Congress http://www.gsmworldcongress.com).

In order to increase the quality of the data, the questionnaire was divided into two parts, to be answered by two individuals. The first part focusing on company-level questions was filled in by the Vice President of Research & Development or the Chief Technology Officer of the respondent company. After filling in the first part, the respondent was asked to select a collaborative case project and to forward the second, project-specific part of the questionnaire to the project manager of the selected case project. The case project had to fulfill the following criteria: First, the product or technology developed within the project had to be telecommunications-specific. Second, the project had to involve some interaction between the technical staff of the partnering firms, as opposed to being a mere outsourcing project. Third, the project had to be finished by the time the questionnaire was filled in.

4.2.1 Sample

Out of the total population of 643 companies, 28 companies reported that the survey did not apply to them (either they had no R&D or R&D collaboration, or they were not operating in the telecommunications industry). These companies were eliminated from the sample, leaving us with a targeted sample of 615 companies. Out of the targeted sample of 615 companies, we received altogether 105 responses, resulting in a response rate of 17,1%. The structure of our sample in terms of geographical location and business area is shown in Figure 9.

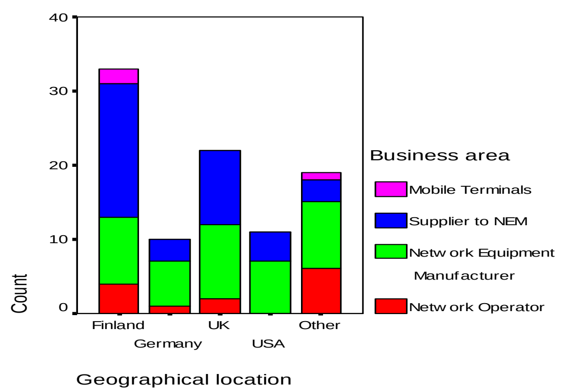

Figure 9. Business area and geographical location of the respondents

The majority of the respondents were relatively small companies, with annual sales of less than 50 Million USD and fewer than 100 employees (Table 8). All in all, we received replies from 19 countries. The non-respondent analysis was performed with the Mann-Whitney U test. Besides our respondents being mainly composed of European firms, the analysis did not show any significant differences between the respondents and non-respondents in terms of amount of employees, net sales or R&D intensity of the company. Finally, we found no differences between the early and late respondents, or responses delivered through a paper or Internet questionnaire.

Employees	%	Cum-%	Net Sales, mUSD	%	Cum-%
1-10	10	10	<=1	24,4	24,4
11-100	50	60	1-10	28,9	53,3
>100	40	100	>10-50	23,4	76,7
			>50-1000	14,3	91
			>1000	9	100

Table 8. Respondent distribution of Employees and Net Sales

4.3 Constructs

4.3.1 Cluster Variate: Knowledge Conversion Processes

Prior literature suggests that it is possible to operationalize the highly intangible knowledge conversion processes by using various knowledge transfer mechanisms as a proxy (Nonaka et al., 2000; Nonaka & Takeuchi, 1995; Sabherwal & Becerra-Fernandez, 2003). We derived the knowledge transfer mechanisms from the study of Smeds et al. (2001) focusing on inter-unit R&D collaboration within the ICT industry. Following the example of prior literature, the knowledge transfer mechanisms were classified according to the four knowledge conversion processes (Nonaka & Takechi, 1995; Sabherwal & Becerra-Fernandez, 2003). This classification was confirmed by means of factor analysis (see Table 2). For each of these knowledge transfer mechanisms, the project manager was asked to indicate on a scale from 1 to 7 how frequently a particular knowledge transfer mechanism was used between the partners of an R&D alliance.

Knowledge transfer mechanisms supporting socialization include face-to-face interaction, joint activities and spending time together rather than giving or receiving written and verbal instructions (Nonaka & Konno 1998). In R&D partnerships, companies sometimes co-locate some of their employees at their partner company (e.g. Hirvensalo et al., 2003). Among other purposes, co-location may aim at transferring knowledge from the more experienced company to the less experienced partner. In addition, this knowledge transfer may take place through coaching, job rotation or the use of process consultants. In addition, co-location may allow the team members to engage in informal corridor talk, during which experiences and other tacit knowledge may be exchanged (Hirvensalo et al., 2003).

Externalization often requires that an individual feels being part of the group in order to convert his or her tacit knowledge into a form easily understandable to others (Nonaka and Konno, 1998). In R&D alliances with team members coming from different organizations, the "team spirit" needs to explicitly created. Various meetings may serve as occasions bringing team members together and providing a possibility for the explication and conceptualization of tacit knowledge on the collaborative R&D project and its management practices. Based on Smeds et al. (2001), the most widely used meetings include design review, test specification, test results review, prototype review and milestone review meetings.

Combination involves gathering, combining, disseminating, editing and storing of explicit knowledge. It is characterized by collective, often virtual interaction (Nonaka & Konno, 1998, Nonaka & Takeuchi, 2000). In projects conducted a within single organization, combination may occur through meetings and creation of documents (Nonaka & Konno, 1998). In inter-organizational R&D projects, face-to-face meetings take place less frequently. This is why other mechanisms gain more importance. According to Smeds et al. (2001), the most frequently used means for the combination of explicit knowledge items include the use of e-mail distribution lists and telephone conferences. In addition, new knowledge created through combination is often stored in written process descriptions, project documentation, progress reports and other knowledge repositories (Nonaka & Konno 1998, Sabherval & Becerra-Fernandez, 2003).

According to prior literature focusing mainly on knowledge conversion processes within a single organization, internalization involves the transformation of explicit knowledge into the tacit knowledge through learning by doing, simulation, observation and training (Nonaka & Konno, 1998). R&D alliances, however, provide fewer possibilities for these kinds of activities. Therefore, we assume that individuals operating in inter-firm settings may mainly resort to studying final reports and listening to presentations, when trying to assimilate explicit knowledge on collaborative R&D practices. In R&D projects, the most critical presentations and reports include lessons learnt presentations and reports, visual process maps, final reports and final customer reports (Smeds et al. 2001). Table 9 presents the knowledge conversion process constructs and the results of the reliability and factor analyses.

Socialization (tacit-to-tacit)		**Externalization** (tacit-to-explicit)	
• Co-location	.653	• Design Review Meetings	.870
• Coaching	.681	• Test Spec Review Meetings	.729
• Corridor Talk	.585	• Test Results Review Meetings	.880
• Job rotation	.845	• Prototype Review Meetings	.819
• Process consultants	.821	• Milestone Review Meetings	.825
Alpha = .76 Var. expl. = 52,5%		Alpha = .88 Var. expl. = 68%	
Internalization (explicit-to-tacit)		**Combination** (explicit-to-explicit)	
• Lessons learnt presentations	.699	• E-mail (p-to-p)	.872
• Lessons learnt reports	.812	• E-mail ditribution lists	.743
• Visual process maps	.762	• Telephone Conferencing	.653
• Final customer reports	.680	• Progress reports during project	.717
• Final reports	.795	• Project Documentation	.655
		• Written Process Descriptions	.626
Alpha = .80 Var. expl. = 56%		Alpha = .75 Var. expl. = 46%	

Table 9. Knowledge Transfer Mechanisms and Results of the Confirmatory Factor Analysis

4.3.2 Outcome of R&D alliances: Learning measures

We use two sets of measures when assessing the learning outcomes of R&D alliances. These measures include perceptive learning measures and improvements in collaborative R&D processes adopted by partnering firms.

Perceptive learning measures

The perceptive learning measures assess the degree to which the respondents feel that they have learned from the partners' R&D processes and ways to collaborate. These measurement items were developed based on prior research on R&D collaboration in the telecommunications industry (Feller et al., forthcoming). Following Cohen & Levinthal (1990) and Lane & Lubatkin (1998), we decided to focus both on general and partner-specific cooperation skills, as shown in Table 3. The items were rated both by the senior technology manager and the project manager on a seven-point Likert scale. For each item, the intra-class correlation (ICC) measure was calculated. Three items showed a sufficiently high ICC correlation, and were thus combined[19]. For the five items focusing on a specific R&D alliance, we decided to use the replies provided by the project manager. For the remaining two items – those concerning non-R&D collaborations – we decided to use the responses provided by the senior technology manager, since a person in a senior position can be expected to be more familiar with activities outside his or her specific field than a project manager.

			Factor loading		
Items	ICC	p-value	R&D collaboration	Non-R&D collaboration	R&D processes
In this project, we learned about our partner's R&D process	.49	**0.05**	.08	-.02	**.89**
We use this knowledge in our company's own R&D	**.65**	**< 0.01**	.31	.22	**.77**
In this project, we learned from our partner ways to cooperate with our partner company	.51	**0.04**	**.76**	-.12	.21
In this project, we learned from our partner ways to cooperate with other companies	.46	0.07	**.78**	.28	-.03
We use this knowledge in other R&D Cooperations with this partner	**.59**	**0.01**	**.80**	.11	.20
We use this knowledge in other R&D Cooperations with other partners	**.60**	**0.01**	**.79**	.22	.16
We use this knowledge in other non-R&D Cooperations with this partner	.48	0.07	.14	**.92**	.18
We use this knowledge in other non-R&D Cooperations with other partners	.49	0.06	.13	**.93**	-.01

Two-way-mixed ICC, confidence interval 95%. Factor analysis: Principal component analysis, Varimax rotation

Table 10. Intra-class correlations and factor loadings for perceptive learning measures

Based on the results of a factor analysis, it was possible to identify three distinct perceptive learning measures focusing on learning from 1) the partner's R&D processes; 2) R&D collaboration in general and 3) non-R&D collaboration in general. The Cronbach's alphas for these measures were sufficiently high ranging from .67 to .89. The three factors explained 75 percent of the total variance.

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[19] For those cases for which only one answer was available, this answer was used

Improvements in collaborative R&D processes

The measure for improvements in collaborative R&D processes was developed based on a multiple case study reported in Feller et al. (forthcoming). This study identified several improvements in collaborative R&D processes of alliance partners, such as the introduction of joint project planning and evaluation meetings, improved use of prototyping - especially the use of intermediate prototypes-, improvements in release management, joint milestones, as well as clear allocation of tasks and responsibilities. Of these collaborative R&D process improvements listed above, the management of prototypes, definition of milestones and clear allocation of tasks and responsibilities are key characteristics of advanced R&D processes and are the main determinants of time to market (e.g. Wheelwright and Clark 1992, p. 136). These three items were thus included in the construct. A novel item derived from our case study was improved release management, deemed of outmost importance in rapidly evolving high-tech industries, such as the telecommunications. This managerial practice originating from the software industry synchronizes the rapid clock speed of launching new product releases to the market with the slower pace of marketing and customer relationship management. In collaborative R&D projects, synchronizing the introduction of new product releases and their marketing is highly important, but also very hard to achieve. These four items were rated by both the senior technology manager and the project manager on a seven-point Likert scale. For each item, the intra-class correlation coefficient was calculated, as shown in Table 5. As all ICC scores were above 0.65 ($p<0.01$) (cf. Boyer and Lewis 2002, Boyer and Verma 2000), we were able to form a combined measure using the data from both respondents.[19] The factor analysis shows that all four items load on one factor.

Items	ICC	p-value	loading
The project helped us to improve our use of prototypes in collaborative projects.	.67	p < 0.01	**.64**
The project helped us to improve our release management in collaborative R&D projects	.65	p < 0.01	**.79**
Through the project, we learned to better divide tasks & responsibilities in collaborative R&D projects	.69	p < 0.01	**.79**
The project has improved our use of milestones in collaborative projects	.83	p < 0.01	**.87**
Average ICC	.71		

Two-way-mixed ICC, confidence interval 95%; Factor loading: unrotated principal component analysis; Var. exp. = 60%, Cronbach alpha = .77

Table 11. Intra-class correlation and factor loadings / improvements in collaborative R&D processes

4.3.3 Firm Characteristics

The firm characteristics were assessed with the single-item measures for the number of employees, the net sales (in million USD), the R&D intensity measured as the ratio of R&D expenditures to net sales, the number of collaborative R&D projects during the previous three years, and the motivation for initiating the collaborative R&D project. The items were rated on a seven-point likert scale. The motivations items include improving own creativity through R&D alliances and sharing cooperation skills with the partner. The first four questions were addressed to the senior technology manager, while the questions concerning the motivation for the case project were directed to the project manager.

4.3.4 Alliance Characteristics

Earlier cooperation experience

Prior collaboration facilitates communication through the emergence of informal ties and trust between the collaborating partners. Companies with a long history of prior collaboration may also have developed so-called relative absorptive capacity facilitating learning from each other (Lane and Lubatkin, 1998). This construct was operationalized with three self-developed measurement items. For measurement items and factor loadings, please refer to Table 12.

Items	Earlier cooperation experience
Our company's project members had extensive earlier cooperation experience with our partner	**.93**
Our partner's project members had extensive earlier cooperation experience with our company	**.85**
The project members from both sides have worked previously with each other	**.91**

Principal component analysis; Var. exp. = 81%; Cronbach alpha = .88

Table 12. Measurement Items and Factor Loadings, Earlier Cooperation Experience - Construct

Contractual and procedural governance

The measures of contractual and procedural governance reflect the detailedness of governance mechanisms used in an R&D alliance. The questionnaire items are partly based on previous research (Noteboom et al., 1997) and have been modified for this study. The factor analysis provided us with two separate constructs, labeled as contractual and procedural governance, as shown in Table 13. All items were rated by the project manager on a seven-point Likert scale.

Items	Contractual governance	Procedural governance	Source
The agreement on outcome rights was very detailed	**.78**	.19	Noteboom et al. 1997
The joint risk sharing agreement was very detailed	**.84**	.24	Noteboom et al. 1997
The contract specified the cooperation process in great detail	**.67**	.00	
Our internal rules on what knowledge we share with our partner were very detailed	**.63**	.44	
Our company had developed specific R&D procedures for our partner to follow	-.03	**.91**	
We closely monitored the extent to which the partner firm followed the established R&D procedures	.31	**.70**	
Our company regularly monitored to which extent our partner met the goals specified in the contract	.21	**.64**	

Principal component analysis, Varimax rotation; Var. exp. = 61,5%; Cronbach alphas = .77 / .69

Table 13. Factor loadings, governance constructs

Interorganizational Trust

Inter-organizational trust relates to the expectations concerning the non-opportunistic behavior of the alliance partner, or, as Kale at al. (2000) put it, the "confidence the partners have in the reliability and integrity of each other". In other words, the construct refers to mutual trust, respect and friendship within a relationship. The existence of trust has a twofold effect: on one hand, it facilitates learning by improving the information flow between the partners; on the other hand, it minimizes the risk of opportunistic behavior within an alliance. Table 14 presents the measurement items and factor loadings for the Inter-Organization Trust – construct.

Table 14. Measurement items and factor loadings, Inter-Organizational Trust - Construct

Items	Inter-Organizational Trust	Reference source
The project was characterized by mutual trust between us and the partner at multiple organizational levels	**.87**	Kale et al. (2000), Dyer and Singh (1998)
Our partner has the reputation of being a reliable cooperation partner	**.87**	self-developed

Principal component analysis; Var. exp. = 75%; Cronbach alpha = .67

Knowledge Complementarity and Similarity

The questionnaire items measuring knowledge overlap have been developed based on prior literature (Davis et al., 1992; Woo et al., 1992; Sapienza et al., 2004; Sorrentino & Williams, 1995). They were rated by the project manager on a seven-point Likert scale. A factor analysis produced two factors, labeled as knowledge similarity and knowledge complementarity. Table 15 below displays the measurement items and the factor loadings for these constructs.

Items	Knowledge complementarity	Knowledge similarity
The technical knowledge & skills of our partner were very similar to our company's skills	.02	**.88**
The R&D management capabilities of our partner were very similar to us	.21	**.83**
Our company and our partner complemented each other's technical knowledge	**.90**	.01
Our company and our partner complemented each other's R&D management capabilities	**.85**	.22

Principal component analysis, Varimax rotation; Var. exp. = 77%; Cronbach alphas = .65 / .71

Table 15: Measurement items and factor loadings, knowledge overlap constructs

5 Results

The three-cluster solution is examined from an inside-out perspective in Table 10. In the inside-out perspective, the differences in the means of variables included in the cluster analysis are compared across the three clusters. The Kruskall-Wallis test indicates that all three clusters differ from one another in terms of their use of knowledge transfer mechanisms supporting socialization, externalization, combination and internalization. Figure 10 graphically presents the differences between the clusters.

	Cluster 1 N = 10	Cluster 2 N = 32		Cluster 3 N = 25	
			% of cl. 1		% of cl. 1
Socialization[a]	4,84***	3,11***	64 %	2,25***	46 %
Externalization[a]	6,2***	5,38***	87 %	3,14***	51 %
Combination[a]	6,22***	5,06***	81 %	3,71***	60 %
Internalization[a]	5,12***	3,71***	72 %	1,94***	38 %

a Kruskal-Wallis Test *** = p < 0,001

Table 16. Inside-Out Analyses

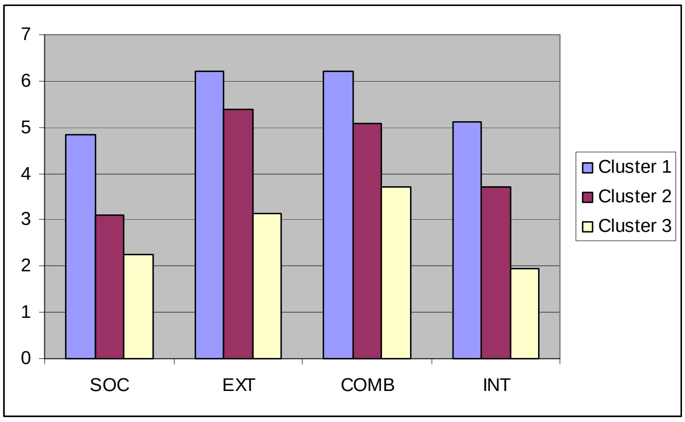

Figure 10: Use of SECI processes by cluster

In Table 17, the three-cluster solution is analyzed from an outside-in perspective. The focus is on the characteristics of partnering firms, the characteristics of an alliance, characteristics of the technology being developed, as well as the learning outcome of the R&D alliance. As Table 17 indicates, the three clusters differ from one another in terms of all these variables not included in the cluster variate. The interpretation of the results of the cluster analysis will be presented below.

		Cluster 1 N = 10	Cluster 2 N = 32	Cluster 3 N = 25
Firm Characteristics	Collaborative R&D projects (last 3 yrs), Median,[a]	20**	10**	3**
	Employees (Median),[b, e]	625$^+$	100$^+$	40$^+$
	Motivation: Improve own creativity,[b]	5,63$^+$	4,26$^+$	3,96$^+$
	Motivation: Share cooperation skills with our partner,[a]	5,89**	4,03**	3,00**
	R&D/Sales (Median),[a]	6 %	20 %	10 %
Alliance Characteristics	Earlier cooperation experience with partner,[d, a]	4,76$^+$	3,94$^+$	3,48$^+$
	Contractual governance,[c]	5,2***	3,55***	2,83***
	Procedural Governance,[c]	3,3$^+$	3,1$^+$	2,5$^+$
	Interorganizational Trust,[b]	6,1**	5,41**	4,72**
	Knowledge Complementarity,[c]	5,95*	5,37*	4,78*
	Knowledge Similarity,[b]	5,1*	4,22*	3,52*
	Type of innovation			
	Improvement of existing product family	60 %	38 %	16 %
	New product family	30 %	38 %	28 %
	Breakthrough product	10 %	25 %	52 %
Learning Outcomes	Improved collaborative R&D processes,[c]	5,50***	4,50***	3,91***
	Learning: Partner's R&D process,[c,f]	5,03*	4,39*	3,85*
	Learning: R&D Collaboration,[c,d]	5,94***	4,74***	4,77***
	Learning: Non-R&D Collaboration,[b]	4,7*	3,30*	3,56*

a Median test b Kruskal-Wallis Test c ANOVA d transformed to cube e transformed to reciprocal square f transformed to natural log
+ = p < 0,1; * = p < 0,05; ** = p < 0,01; *** = p < 0,001

Table 17: Outside-In Analysis

5.1 Cluster 1: Developers of Incremental Innovations: Seasoned Collaborators from Scandinavian countries

Ten firms forming our first cluster can be labeled as developers of incremental innovations. Two-thirds of these firms state that they use alliances to develop new products for their existing product families. In a similar vein, two-thirds of the R&D alliances investigated in this study focus on improving existing product families. All of these firms are large Scandinavian firms. The median number of employees and net sales are 625 and 42,7 Million USD, respectively. Two-thirds of these firms are suppliers to network equipment manufacturers. 90 percent of R&D alliances in this cluster develop products to be sold either by the alliance partner or a third company. Emphasis on incremental as opposed to radical innovations might explain the fact that this cluster shows the lowest median R&D-to-sales ratio of 6 percent.

Cluster 1 seems to be the most experienced among our three clusters, when it comes to R&D collaboration in general. On average, these companies had participated in 20 collaborative R&D projects during the previous three years. In addition, the alliances in this cluster are also the most international: In 40 percent of the cases the collaborating partners were located in different countries. Interestingly enough, this cluster scores the highest in terms of earlier cooperation experience with the partner of the specific case project. This may explain the fact that the R&D alliances in this group are also characterized by the highest level of trust. A comparison of the three clusters reveals that the firms in this cluster prefer collaboration with rather similar partners in terms of the complementarity and similarity of knowledge bases. Finally, the members of this cluster express having the highest motivation to learn about their partner's R&D process during the collaborative R&D project.

This cluster shows the highest degree of professionalism in managing their alliances. Approximately 60 percent of the companies have centralized the management of their inter-organizational R&D relationships. In terms of the governance of R&D alliances, this cluster uses the most detailed contractual and most intense procedural governance mechanisms among the three clusters. The members of this cluster are also the most active in terms of using knowledge conversion mechanisms related to socialization, externalization, combination and internalization and most successful in terms their adopting new collaborative practices and learning from their partner's R&D processes.

5.2 Cluster 2: Stuck in the Middle: Medium-Sized R&D Intensive Firms Developing both Incremental and Radical Innovations

The firms in the second cluster can be best described as medium-sized R&D intensive firms developing both incremental and radical innovations. This cluster of 32 firms includes network equipment manufacturers (50 percent), network equipment manufacturers (approximately 30 percent), and network operators (18 percent). The cluster composition is roughly the same as of Cluster 3. The companies in this cluster are medium-sized, with a median of 100 employees, and 10 million USD of annual net sales. 38 percent of R&D alliances in this cluster focus on developing new products within existing product families. Another 38 percent are engaged in developing products for totally new product families. The remaining 25 percent are involved in developing breakthrough products, serving as a basis for establishing a new business area for one or both of the partners to an R&D alliance. Of our three clusters, these firms are by far the most R&D intensive with their median R&D-to-sales ratio of 20 percent. Compared to the following Cluster 3, companies in this cluster invest twice the portion of their sales into R&D.

The companies in the second cluster rank midway between the developers of incremental innovations (Cluster 1) and radical innovations (Cluster 3), in terms of their collaboration experience, the level of inter-organizational trust, willingness to learn from their alliance partners, and the use of contractual and procedural governance mechanisms.

It is notable, that this cluster shows substantially less contractual governance than Cluster 1, whereas Cluster 3 differs to a smaller extent from this cluster. When examining the differences in procedural governance, we find that this cluster is very close to Cluster 1, and the big difference occurs between this cluster and Cluster 3. Companies in Cluster 2 also fall between the first and third cluster relative to their use of knowledge conversion mechanisms.

However, compared to Clusters 1 and 3, the firms in this cluster use socialization mechanisms less frequently than other knowledge conversion mechanisms[20]. This cluster seems to be the least successful in terms of learning from their partner's general ways to collaborate. However, this cluster ranked second in its ability to learn from the partner's R&D processes and to introduce concrete improvements in their collaborative R&D processes, such as the use of prototypes, milestones, release management and more efficient allocation of tasks and responsibilities.

5.3 Cluster 3: Developers of Radical Innovations: Small Collaboration Newbies

The companies in this cluster can be labeled as developers of radical innovations. 64 percent of these 25 firms use R&D alliances to develop breakthrough products or new product platforms. In a similar vein, 52 percent of the R&D alliances included in this study focus on developing breakthrough products. The members of this cluster are mainly small companies with the median number of employees of 40 and median annual net sales of 5 million USD. However, the R&D expenditures in this cluster (10 percent of annual sales) are lower than in Cluster 2 developing both radical and incremental innovations.

This cluster shows the highest proportion of alliance partners (56 percent) assuming the responsibility for marketing and sales of the product developed in collaboration with the partner. Interestingly though, this cluster shows the lowest level of contractual and procedural governance among the three clusters. As for the internationality of alliances, only 20 percent of the firms in this cluster collaborate with partners outside their home country. Surprisingly, the companies in this cluster are the least experienced in R&D collaboration, with a median of only 3 collaborative R&D projects during the previous three years. In a similar vein, the developers of radical innovations are usually unfamiliar with their alliance partner in the case project. It seems to us that the alliances in this cluster are based on ad-hoc relationships, displaying the lowest level of inter-partner trust among the three clusters.

Our findings suggest that the developers of radical innovations use the knowledge conversion mechanisms supporting socialization, externalization, combination and internalization less frequently than the two other clusters. In particular, the use of internalization seems to be the weak spot of firms developing radical innovations.[21]. This

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[20] Compared to Cluster 1 (100 percent), Cluster 2 uses knowledge conversion mechanisms less frequently: socialization (64 percent), externalization (87 percent), combination (82 percent) and internalization (72 percent).

[21] Compared to Cluster 1 (100 percent), Cluster 3 uses internalization mechanisms clearly less (38%). The equivalent figures for socialization, externalization and combination mechanisms are 46 percent, 51 percent and 60 percent, respectively.

cluster was also the least successful in terms of learning about the partner's R&D process and introducing concrete improvements in collaborative R&D practices. However, the members of this cluster rank second after Cluster 1, when learning from the partner's general ways to collaborate is used as a proxy for alliance success.

5.4 Radical vs. Incremental Innovations: Differences in Alliance Characteristics and Learning Outcomes

When comparing Clusters 1 and 3, it becomes evident that that the alliances developing radical and incremental innovations differ from one another in terms of various partner-specific and alliance-specific characteristics as well as their learning outcomes. First, it seems that companies developing incremental innovations favor partnering with their ex-alliance partners possessing similar or complementary knowledge bases. They are also more motivated to use alliances for improving their own creativity and sharing their skills with their partner than firms developing radical innovations. Therefore, it is not surprising that alliances between the developers of incremental innovations are characterized with a higher level of trust than alliances developing radical innovations.

R&D alliances developing incremental innovations use more mechanisms supporting socialization, externalization, combination and internalization than the partnerships focusing on radical innovations. Developers of incremental innovations also learn more from their partner's R&D processes and introduce more often improvements in their collaborative R&D processes. An explanation for this finding might lie in the nature of the product development process: Radical breakthrough projects are infrequent, and they follow a less structured process than the more derivative projects (Wheelwright & Clark, 1992). In other words, the more radical the innovation, the more unpredictable and unique its development process will be, providing fewer opportunities for process learning.

Cluster 2 consisting of firms developing both radical and incremental innovations ranks midway between the two other clusters in terms of their size, motivation to learn from alliances, the degree of procedural and contractual governance, the level of trust, and the use of mechanisms supporting knowledge conversion processes. This cluster ranks also second in terms of introducing concrete improvements in collaborative R&D processes. However, this cluster falls behind the clusters focusing only on radical or incremental innovations in terms of their ability to learn from the partner's ways to collaborate and apply this knowledge to their own processes.

6 Discussion

Our paper contributes to the existing knowledge on managing R&D alliances by establishing a link between three distinct approaches to knowledge creation in R&D alliances, the characteristics of the technology being developed, and the learning outcomes of R&D alliances. The results of this study suggest that various partner and alliance-specific factors may play key role in determining the degree to which it is possible for a company to learn to better manage their inter-organizational R&D processes.

First, our study contributes to the emerging body of literature on managing radical innovations (see, for instance McDermott & O'Connor, 2002; Leifer, O'Connor & Rice, 2001; Rice et al., 2000) by emphasizing the differences in managing alliances developing radical innovations as opposed to incremental innovations. Most importantly, it seems that companies developing incremental innovations are better at upgrading their collaborative R&D processes than companies developing breakthrough products. An explanation for this might lie in the nature of the product development process: The more radical the innovation, the more unpredictable and unique its development process will be, and fewer possibilities there will be for adopting process improvements for future use. Interestingly enough, the developers of both radical and incremental innovations from cluster 2 are the worst equipped in terms of learning new ways to collaborate from their alliance partners. We suspect that the management of radical innovation processes differs so drastically from promoting incremental innovations that most firms face significant difficulties when trying to accomplish these two tasks simultaneously.

Second, we found that companies with extensive prior collaboration experience with their partner (Cluster 1) are better able to upgrade their collaborative processes than partners unfamiliar with each other. An explanation for this may lie in the emergence of relative absorptive capacity and trust during prior relationships, facilitating learning from each other (Lane and Lubatkin, 1998; Kale et al., 2000; Powell, Koput, Smith-Doerr, 1996; Dyer & Singh, 1998; Larsson et al., 1998; Madhok, 1995). Third, in line with prior studies (Sabherwal & Becerra-Fernandez, 2003; Feller et al., forthcoming) our results suggest that a higher overall use of knowledge transfer mechanisms leads to better learning results.

Our study also adds to a better understanding of the use of knowledge transfer mechanisms in R&D alliances. Prior studies have mainly focused on the use of knowledge management mechanisms within a single firm (Smeds et al., 2001; Chai et al, 2003; Corso et al., 2003). To our knowledge, no studies to this date have investigated the differences in knowledge creation mechanisms in alliances developing radical as opposed to incremental innovations. Finally, it has been argued that management scholars and practitioners tend to neglect processes when exploring the antecedents of organizational performance (see, for instance, Hammer, 2004). With our focus on process learning in R&D alliances, we take a preliminary step towards addressing this problem.

7 Limitations of the Study

This study is subject to a number of limitations. First, it has been argued that knowledge creation processes are highly sensitive to the pervasive effect of culture (see, for instance, Glisby & Holden, 2003; Holden, 2001). Thus, a future study is required to explore the emergence of collaborative routines in alliances outside the geographical scope of our sample, i.e. outside Northern Europe and the United States. Second, our theoretical framework leaves much room for interpretation relative to the operationalization of the four knowledge conversion processes. It is possible that particular knowledge transfer mechanisms are mainly used to facilitate one of the knowledge conversion processes, as assumed in prior literature (Nonaka, Toyama & Konno, 2000; Sabherwal & Becerra-Fernandez, 2003) and our study. However, these same mechanisms may also play a minor role in supporting the other knowledge conversion processes. As a result, the operationalization of knowledge conversion processes might require more complex procedures than undertaken in prior literature and this study. In addition, several authors have questioned the way in which Nonaka and Takeuchi (1995) distinguish between explicit and tacit knowledge, regarding it as artificial or even misleading (Araujo, 1998; O'Donnell et al., 2000; Tsoukas, 1996).

Third, studying the link between improvements in collaborative R&D processes, overall performance and innovativeness was beyond the scope of our study. The advocates of process management suggest that process management practices contribute to cost reductions, improved customer satisfaction, and, ultimately, higher profits (Hammer & Stanron, 1999; Harry & Schroeder, 2000). However, there are also studies suggesting that standardization of R&D processes may undermine radical innovations (Benner & Tushman, 2003; 2002). Thus, a future research project could explore, for instance, how process learning associated with collaborative R&D processes affects overall performance and the emergence of radical, as opposed to incremental innovations. Fourth, the scope of the study is limited to the high-velocity telecommunications industry in general, and to R&D collaboration between network equipment manufacturers, their suppliers, and network operators in particular. This may weaken the applicability of our findings in other industrial sectors characterized by a slower speed of product development activities. Finally, an interesting avenue for future research would be investigating the emergence and evolution of collaborative R&D practices over time in a longitudinal research setting.

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ESSAY 4: The Influence of Inter-Partner Competition, Trust, and Knowledge Complementarity on the Effectiveness of Knowledge Transfer Mechanisms for Process Learning

1 Introduction

To keep up with competition, companies need to create new or improved product offerings with high speed, flexibility and reliability. Continuous upgrading of R&D processes has thus emerged as primary target for many organizations as they are starting to extend the application of process management philosophy from initial manufacturing applications to new product development processes (Garvin, 1995; Powell, 1995; Cole, 1998; Repenning & Sterman, 2002). Additionally, embedding individual knowledge in processes and organizational routines is an effective means to reduce the negative impact of personnel turnover (Argote 1999, p.91), making process management and innovation an important tool for managing organizational knowledge and capabilities.

Not only the importance of process innovation has risen, but also has the way companies conduct their product development changed. While R&D used to be conducted on a project basis, then becoming subject to portfolio management, R&D is nowadays an interwoven process of intra- and inter-organizational learning involving the need for managing an extensive amount of knowledge flows. Additionally, a vast amount of companies is conducting at least a part of their R&D in collaborations with other companies, sometimes even competitors. Various studies suggest that inter-firm collaboration spurs innovativeness of the organizations involved (see, for instance, Lee et al., 2001; Cohen & Levinthal, 1990; Hagedoorn, 1993; Teece, 1987; Goes & Park, 1997). The increased popularity of collaboration in R&D, combined with the necessity to improve R&D processes, leads to the need of inter-organizational process learning.

A great number of studies concentrate on the factors influencing inter-organizational learning in general (e.g. Cohen & Levinthal 1990, Prahalad 1993, von Hippel 1994, Szulanski 1996, Lane and Lubaktin 1998, Almeida & Kogut 1999). Previous research also establishes that the source of inter-organizational learning is inter-organizational interaction, which results either in the transfer of existing knowledge or in the creation of new knowledge (Nonaka and Takeuchi 1995, Argote 1999, Nonaka et al. 2000a,b). Some scholars have investigated, what kinds of mechanisms companies use for transferring knowledge (Smeds et al. 2001). However, in order to manage and improve learning between organizations, it is important to know, how the nature of the relationship between these organizations affects these knowledge transfer mechanisms, and whether different mechanisms are affected differently. This question constitutes a research gap, which until now has been addressed by only very few studies. As Argote (1999) puts it: "Research is needed to explore, under which conditions which modes of knowledge transfer are effective."

The study at hand sets out to answer this call by investigating how inter-partner competition, overlap of organizational knowledge bases, and inter-partner trust affect meetings, documents and transfer of people as knowledge transfer mechanisms for process learning. This article starts with an overview on existing approaches to classify knowledge transfer mechanisms, to measure knowledge transfer success, and to categorize relationship factors that may influence knowledge transfer success. After that, the hypotheses are introduced and tested, and the results are presented and discussed. The paper ends with an investigation of the limitations and proposals for future research.

2 Classifying Knowledge Transfer Mechanisms

Depending on the focus of research, previous studies provide different approaches to classify knowledge transfer mechanisms (KTMs) within and across organizations.

First, knowledge transfer mechanisms have been classified according to the stage of the overall knowledge transfer process during which they are applied (e.g. Szulanski 2000). Classifications following this scheme group knowledge transfer mechanisms in categories like initiating, implementing, ramp-up and integrating mechanisms. Research following this approach usually aims at explaining how different stages of the knowledge transfer are influenced by external factors.

Second, mechanisms for knowledge transfer have been categorized according to their location in the organization's environment. One example is the study by Appleyard (1996), where different mechanisms were grouped according to whether they were based within a company, in other companies, in collaborating organizations or in professional fora such as conferences. The aim of the study was to assess the effectiveness of these groups of mechanisms for the transfer of technical information.

A further way for classification is to categorize knowledge transfer mechanisms following existing theoretical frameworks. Using this approach, mechanisms have been for example classified into mechanisms supporting the socialization, explication, combination and internalisation phases of the Nonaka & Takeuchi (1995) knowledge sharing model (see e.g.

Essay 2, Johnson & Johnston 2004, Sabherwal, & Becerra-Fernandez 2003). Studies following this approach are mainly aimed at theory enhancement and verification.

The fourth, most straightforward means of classification are the characteristics of the medium. In this stream, knowledge transfer mechanisms have been classified into mechanisms consisting of meetings and presentation (Smeds et al. 2001, Edquist et al. 2002, Argote 1999), into mechanisms concerning the transfer of people (Edquist et al. 2002, Argote 1999, Galbraith 1990), into mechanisms based on training (Smeds et al. 2001, Argote 1999), into electronic or virtual mechanisms (Butler 2003, Kraut, R. et al. 1990, Bolisani & Scarso 2000, Smeds et al. 2001), and into written documents (e.g. Smeds et al. 2001, Edquist et al. 2002). Whereas research in this area has been mainly of exploratory nature, some researchers have been focusing on the effectiveness of knowledge transfer mechanisms.

This research follows the latter research stream. We classified 17 different knowledge transfer mechanisms used in collaborative R&D into three main groups: *meetings*, the *transfer of people*, and *written documents*. The single knowledge transfer mechanisms used are based on the work of Smeds et al. (2001), who investigated the use of knowledge transfer mechanisms in inter-unit collaborative R&D. The classifications as well as the results of reliability- and confirmatory factor analysis are presented further down together with the other constructs of this study.

3 Measuring Knowledge Transfer Success

Measuring knowledge transfer and its success is challenging (Argote 1999). Many studies try to measure knowledge transfer success based on proxies such as improved productivity (e.g. Argote 1999, Arrow 1962), number of new products introduced (Tsai 2001), reduced leadtime and waste (Kalling 2003) or increased share price (Anand & Khanna, 2000).

In order to assess the success of knowledge transfer more directly, previous research displays four approaches (Cummings & Teng 2003). The most basic measurement level is the number of knowledge transfers that have taken place. Probably due to its purely quantitative dimension, this approach seems nevertheless to be used very rarely (for an example see Hakanson and Nobel 1985, ref. Cummings and Teng 2003).

A second, more popular approach stems from the area of project management (Pinto and Mantel 1990). Here, previous studies focussing on knowledge transfer success assessed, whether certain measurable aims for the knowledge transfer were reached. Measurement criteria used here are such as the transfer being on time, within budget, and the recipient being satisfied (Szulanski 1996,von Hippel 1994)

Within the realm of institutional theory, some studies assess the success of knowledge transfer based on whether the knowledge is internalised. These studies mostly focus on internalisation into individual, not organizational knowledge bases. Successful internalisation takes place, when the recipient obtains ownership of the knowledge transferred, is satisfied and commits to the received knowledge (Cummings & Teng 2003).

Drawing on the roots of organizational learning theory, the last stream of research measures knowledge transfer as the degree of successful re-creation in the recipient: Mastering and applying processes, organizational structures or product designs transferred (e.g. Essay 2, Nelson 1993, Urabe 1988, Smeds 1994). The rationale behind this approach lies in the argumentation, that successful knowledge transfer has not taken place before the transferred processes, structures or designs have been successfully implemented (Urabe, 1988). This approach is also adopted in this study. I assess the success of knowledge transfer with help of a specific organizational learning construct called process learning. The construct has been developed in previous case research (Feller et al., forthcoming), and consists of a set of implemented improvements in the collaborative R&D process of companies. The items of this measure were rated by two independent members of each organization. The measure was verified since the inter-rater correlation between each pair of answers was significant and high enough[22].

4 Previous Research on Factors Affecting Knowledge Transfer Success

Previous research on factors affecting the success of knowledge transfer has focused on three different areas: the nature of the knowledge to be transferred, the characteristics and behavior of sender and recipient, and the characteristics of the relationship between sender and recipient.

Research investigating on how the nature of knowledge influences its transferability has come up with a number of partly overlapping factors. Von Hippel (1994) and Szulanski (1996) have been investigating the 'stickiness' of knowledge, i.e. the fact that certain knowledge is more costly to transfer than other. Among others, Prahalad (1993) and Almeida

[22] See chapter 6.3.3

& Kogut (1999) have researched the effect of knowledge embeddedness into sites, assets, routines and individuals on the success of knowledge transfer. A study by Galbraith (1990) investigated the effect of knowledge complexity on its transferability. Finally, an extensive body of literature is concerned with the tacitness of knowledge and its effects on knowledge transfer success (Polanyi 1966, Zander & Kogut 1995, Nonaka & Takeuchi 1995).

One stream of research focuses on the characteristics and behavior of sender and recipient, and their influence on knowledge transfer success. In the recipient perspective, a central area is grouped around the construct of absorptive capacity (Cohen & Levinthal 1990), i.e. the capability to recognize the value of new, external information, to assimilate it and to apply it to commercial ends. Whereas learning-by doing enables a firm to become more efficient in what it already does, absorptive capacity enables the firm to acquire knowledge that enables it to perform new, unknown activities. Other research foci within the realm of recipient characteristics are amongst others previous experience in knowledge transfer (e.g. Galbraith 1990), and motivation (Szulanski 2000, Szulanski 1996, Kalling 2003). Other researchers have taken the perspective of the sender, and investigated the influence of company size (Haunschild & Miner 1997), organizational transparency (Larsson et al. 1998) and overall interorganizational cooperation strategy (Larsson et al. 1998).

Extending the focus from mere company characteristics to the characteristics of the inter-company relationship leads to the last approach. A central construct in this realm is relative absorptive capacity (Lane & Lubatkin 1998), measuring an organization's capability to absorb knowledge from a specific partner in a specific relationship. Relative absorptive capacity can be divided into three capabilities: The ability to recognize and value new external knowledge, the ability to assimilate new external knowledge and the ability to commercialize new external knowledge. These abilities are developed, when the partners in a learning dyad have a common knowledge base, similar knowledge processing structures, and are facing at least partly the same organizational problems and commercial objectives. On a more macro level of analysis, researchers have investigated amongst others how the existence of superordinate ties between organizations (Argote 1999) and the overall quality of the relationship (Szulanski 1996) influence knowledge transfer between organizations.

The research focus of this study lies in the *nature of the relationship* between two collaborating companies and its influence on the *effectiveness of knowledge transfer mechanisms* for inter-organizational process learning. The study is conducted by drawing together factors suggested by different previous studies, and assessing their impact on the effectiveness of knowledge transfer mechanisms measured as process learning. Previous literature suggests, that generally the use of certain knowledge transfer mechanisms is positively correlated with successful knowledge transfer. These mechanisms are especially meetings and face-to-face personal contacts such as the transfer of people (Epple et al. 1991, Darr et al. 1996, Ingram & Baum 1997), and to a certain extent various written documents such as lessons-learnt reports or final customer reports (Szarka et al. 2004).

5 Relationship Factors Affecting Inter-organizational Learning

A number of relationship factors have been suggest to generally affect the learning outcome of inter-organizational learning. This study focuses on inter-partner competition, complementarity of organizational knowledge bases and inter-partner trust.

5.1 Inter-partner Competition

The *competitive situtation* between the two collaborating company undoubtedly influences the effectiveness of knowledge transfer mechanisms. Companies try to prevent the spillover of critical knowledge to competitors. However, collaborating companies might be even more motivated to learn from their partner, if this partner is a competitor. Various studies have shown, that under competition, companies try to learn faster than their competitor, thus engaging in so-called learning races (Child 2001, Dussauge et al. 2000). These learning races occur especially in situations, where the collaborating companies feel that they are able to reach private benefits through this collaboration, that are not available to their partner (Khanna et al. 1998). Improvements of a company's own process for collaborative R&D constitute such a private benefit. Previous research has also shown a positive impact of competition on learning within the setting of inter-team or inter-business unit competition (Szarka et al. 2004). Accordingly, we argue that once competing companies have decided to jointly develop a product, the positive effects of competition on process learning will overweigh the negative effects of spillover prevention on process learning. An increased competitiveness will make a company try to assimilate as much knowledge from the collaborating competitor as possible. Competition should positively affect all three types of KTMs. Thus, we hypothesize that:

Hypothesis 1: Competition positively moderates the effect of all KTMs on process learning.
Hypothesis 1a: Competition positively moderates the effect of meetings on process learning.
Hypothesis 1b: Competition positively moderates the effect of transfer of people on process learning.

Hypothesis 1c: Competition positively moderates the effect of documents on process learning.

5.2 Complementary Organizational Knowledge Bases

It is obvious that in order to enable collaborating companies to learn from each other, the partner's knowledge bases need to complement each other (Sapienza et al., 2004). If the knowledge bases are completely similar, there is nothing to learn. The more complementary these knowledge bases are, the more knowledge there is to exchange. Cohen and Levinthal (1990) argue that a common knowledge base combined with differences in specialized knowledge is positively related to the absorptive capacity of an organization. An increased absorptive capacity in turn leads to higher organizational learning.

However, one has to bear in mind that the knowledge base of the organisation is not the same thing as the sum of the individual knowledge bases of its members. Individuals always possess knowledge that for one reason or another is not available to the organization (Pautzke 1989, Nonaka and Takeuchi 1995). Knowledge complementarity in this study relates to the official picture an organization has about the complementarity of its partner organization's knowledge base. Complementarity of organizational knowledge bases thus influences mostly meetings and written documents – mechanisms that mostly act on the organizational or project level and thus mainly transfer knowledge between the organizational, not the individual knowledge bases. In contrast to these mechanisms, the transfer of people enables exchange of personal experiences and knowledge not included in the organizational knowledge base (Nonaka et al. 1998, Nonaka et al. 2000a).

Thus, we hypothesize that

Hypothesis 2: Complementarity of organizational knowledge bases positively moderates the effect of organization- and project level KTMs on process learning.
Hypothesis 2a: Complementarity of organizational knowledge bases positively moderates the effect of meetings on process learning.
Hypothesis 2b: Complementarity of organizational knowledge bases positively moderates the effect of documents on process learning.

5.3 Behavioral Trust

Behavioral trust relates to the expectations that a firm has concerning the non-opportunistic behavior of its partners (Madhok 1995), or, as Kale et al. (2000) put it, the "confidence partners have in the reliability and integrity of each other". They name this type of trust "relational capital". This construct refers to the mutual trust, respect and friendship within a relationship. The existence of relational capital minimizes the risk of opportunistic behavior within an alliance. Most alliances try to reduce this risk by defining the companies' core or proprietary assets and then develop formal – often written, or informal "codes of conduct" to prevent other partners from appropriating those assets. Formal codes of conduct are subjected to less risk of being broken or misinterpreted, but are on the other hand more costly to impose, whereas informal codes provide higher flexibility combined with higher risk. Written guidelines act as a safeguard for knowledge transfer mechanisms that can be governed by formal codes of conduct (Dyer and Singh 1998, Kale et al. 2000). For the kind of informal exchange of knowledge that takes place through transfer of people, behavioral trust is the safeguard that gives the partners the secure feeling needed to freely share knowledge (Yli-Renko 1999, Kale et al. 2000). Compared to the use of documents and formal meetings, it is relatively hard to formulate written agreements and rules on how knowledge flows through the transfer of people to the partner organization (Dyer and Singh 1998). The high amount of informal interaction and transfer of tacit knowledge requires an existing base of behavioral trust between the partners to act as a safeguard mechanism.

Thus, we propose that
Hypothesis 3: Inter-organizational behavioral trust moderates the effect of transfer of people on process learning.

6 Method

6.1 Data Collection

The data for this study was gathered through an international survey conducted during the years 2002-2003. Our questionnaire was developed based on the prior literature on strategic alliances and two case studies conducted within the R&D Net project at the SimLab research unit of Helsinki University of Technology. The case studies were explorative in nature, analyzing inter-partner learning in two collaborative R&D projects within the Finnish telecommunication industry. The data collection for case studies involved interviews, business process simulations (cf. Smeds and Alvesalo 2003), debriefing sessions and follow-up interviews with the project managers for verification of the findings (for a more detailed description of the case studies, please see Hirvensalo et al., 2003 and Feller et al., forthcoming). We used the case studies mainly for gaining a better understanding of knowledge conversion processes and developing our dependent variable, the improved capability to manage collaborative R&D processes.

The targeted population in our survey was the network operators, network equipment manufacturers, and suppliers to network equipment manufacturers in the telecommunications industry in Europe, Northern America and Asia. The sample companies were identified by using company directories, industry associations and trade fair exhibitor catalogues[23].

Before sent out, the questionnaire was tested both by the employees of the pilot companies[24] and the usability laboratory of Helsinki University of Technology. Data collection started with two rounds of mailings to 517 companies in 72 countries. This resulted in only 20 responses. To increase our response rate, the questionnaire was posted on the Internet. By accessing new databases, we were able to add 126 new companies from Finland, Germany, the UK and the US to the sample. We contacted all potential respondents by phone, after which we sent them an e-mail message containing the link to the survey and some additional instructions. The second round produced the majority of the responses, altogether from 85 firms.

In order to increase the quality of the data, the questionnaire was divided into two parts, to be answered by two individuals. The first part focusing on company-level questions was filled in by the Vice President of Research & Development or the Chief Technology Officer of the respondent company. After filling in the first part, the respondent was asked to choose a collaborative case project and to forward the second, project-specific part of the questionnaire to the project manager of the case project. The case project had to fulfill the following criteria: First, the product or technology developed within the project had to be telecommunications-specific. Second, the project had to involve some interaction between the technical staff of the partnering firms, as opposed to being a mere outsourcing project. Third, the project had to be finished by the time the questionnaire was filled in.

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[23] The online sources used were Hoover's Online (www.hoovers.com), Europages (www.europages.com), the Applegate Directories (www.applegate.co.uk), Kellysearch (www.kellysearch.com), Global Sources (www.globalsources.com), Vendora (www.komponentit.com), Yahoo (www.yahoo.com), Yritystele (www.yritystele.fi), Inoa (www.inoa.fi), The GSM association (www.gsmworld.com), UMTS Forum (www.umts.org), CeBit Trade Fair (www.cebit.de), GSM World Congress http://www.gsmworldcongress.com).

[24] The pilot companies include the companies from the previous case studies reported in Hirvensalo et al. (2003) and Feller et al. (Forthcoming).

6.2 Sample

Out of the total population of 643 companies, 28 companies reported that the survey did not apply to them (either they had no R&D or R&D collaboration, or they were not in the telecommunications industry). These companies were eliminated from the sample, leaving us with a targeted sample of 615 companies. Out of the targeted sample of 615 companies, we received 105 responses, resulting in a response rate of 17,1%.

Most of our sample companies were network operators, network equipment manufacturers, and suppliers to network equipment manufacturers. In addition, a few companies were active in the area of mobile terminals, as shown in Figure 9.

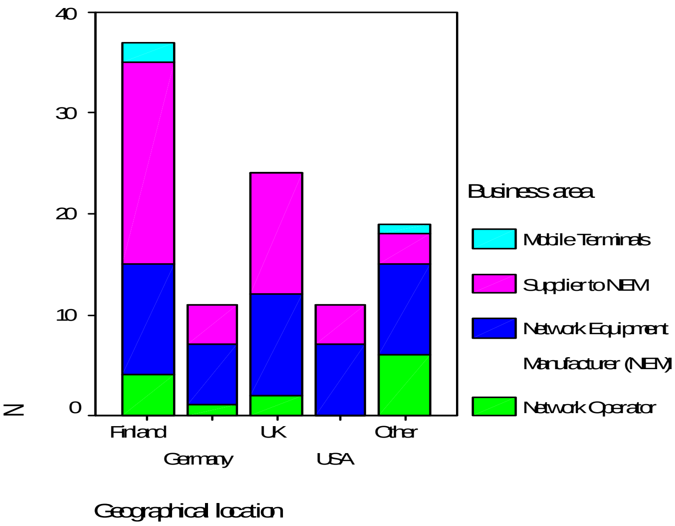

Figure 11: Business area and geographical location of the respondents

As shown in Table 8, most of the respondents were relatively small companies, with annual sales of less than 50 Million USD and fewer than 100 employees. The respondents were located mainly in Finland (35), the UK (22), the US (13) and Germany (10). All in all, we received replies from 19 countries. Besides our respondents being mainly composed of European firms, the non-respondent analysis did not show any significant differences between the respondents and non-respondents in terms of amount of employees, net sales or R&D intensity of the company. Finally, we found no differences between the early and late respondents, or responses delivered through a paper or Internet questionnaire.

Table 18: Respondent distribution of Employees and Net Sales

Employees	%	Cum-%	Net Sales, mUSD	%	Cum-%
1-10	10	10	<=1	24,4	24,4
11-100	50	60	1-10	28,9	53,3
>100	40	100	>10-50	23,4	76,7
			>50-1000	14,3	91
			>1000	9	100

6.3 Constructs

6.3.1 Knowledge Transfer Mechanisms

We derived the knowledge transfer mechanisms from the study of Smeds et al (2001) focusing on inter-unit R&D collaboration in the ICT industry. Following the example of prior literature described above, the knowledge transfer mechanisms were classified into *meetings*, *documents* and *transfer of people*. This classification was confirmed by the means of factor analysis. For each of these knowledge transfer mechanisms, the project manager was asked to indicate on a scale from 1 to 7 how frequently a particular knowledge transfer mechanism was used between the partners to an R&D alliance.

Meetings include meetings for design review, test specification, test results review, milestone review and prototype review. Table 19 presents the factor loadings of the measurement items.

Table 19: Measurement items for meetings

Item	Factor loading
Design review meetings	0.87
Test specification meetings	0.73
Test results review meetings	0.88
Milestone review meetings	0.83
Prototype review meetings	0.82
Principal component analysis	

The factor analysis explained 68% of the variance, the Cronbach-alpha was 0.88.

Documents include lessons-learnt-reports, visual process maps, written process descriptions, final customer reports, progress reports during the project, project documentation, and final reports. Table 20 presents the factor loadings of the measurement items.

Table 20: Measurement items for documents

Item	Factor loading
Lessons-learnt-reports	.70
Visual process maps	.74
Written process descriptions	.67
Final customer reports	.70
Progress reports	.71
Project documentation	.64
Final reports	.81
Principal component analysis	

The factor analysis explained 51% of the variance, the Cronbach alpha was .84.

Transfer of people includes the inter-company use of teamwork within and across functions, co-location, job rotation and process consultants. Table 21 displays the factor loadings of these measurement items.

Table 21: Measurement items for transfer of people

Item	Factor loading
Team-work within functions	.73
Team-work across functions	.73
Co-location	.62
Job rotation	.77
Process consultants	.75
Principal component analysis	

The factor analysis explained 52% of the variance, the Cronbach alpha was .76.

6.3.2 Moderators

Competition

The questionnaire items measuring the competitive situation between the respondent organization and its partner were self-developed and have been rated by the project manager on a seven-point Likert scale. The three items concerned the current competition between the organizations, existence of substitutor products, and the possibility of the partner becoming a competitior in the future. A factor analysis presented one factor, explaining 71% of the total variance. The Cronbach alpha for the three items was 0.79, indicating a sufficient level of internal consistency.

Organizational Knowledge Complementarity

The questionnaire items measuring organizational knowledge complementarity have been developed based on prior literature (Davis et al., 1992; Woo et al., 1992; Autio et al., 2004; Sorrentino & Williams, 1995). The two items concerned knowledge complementarity between the partner organizations in the technical and R&D management fields, and they were rated by the project manager on a seven-point Likert scale. A factor verified that the items were loading on one factor, explaining 76 percent of the total variance. The Cronbach alpha for organizational knowledge complementarity was 0.67.

Inter-organizational Trust

Inter-organizational trust relates to the expectations concerning the non-opportunistic behavior of the alliance partner. We measured interorganizational trust with two measurement items concerning the existence of mutual trust between the organizations and the perceived reliability of the partner organization. The factor analysis explains 75 percent of the total variance. The Cronbach alpha for the items representing inter-organizational trust was 0.67, respectively.

6.3.3 Dependent Variable: Process Learning

The measure for the improved capability to manage collaborative R&D processes was developed based on a multiple case study reported in Feller et al. (forthcoming). This study identified several improvements in collaborative R&D processes of alliance partners. These improvements may be interpreted as improved capability to manage collaborative R&D processes. These improvements include the introduction of joint project planning and evaluation meetings, improved use of prototyping – especially the use of intermediate prototypes, improvements in release management, joint milestones, as well as clear allocation of tasks and responsibilities.

Of these collaborative R&D process improvements listed above, the management of prototypes, definition of milestones and clear allocation of tasks and responsibilities are key characteristics of advanced R&D processes and are the main determinants of time to market (e.g. Wheelwright and Clark 1992, p. 136). These three items were thus included in the construct. A novel item derived from our case study was improved release management, deemed of outmost importance in rapidly evolving high-tech industries, such as the telecommunications. This managerial practice originating from the software industry synchronizes the rapid clock speed of launching new product releases to the market with the slower pace of marketing and customer relationship management. In collaborative R&D

projects, synchronizing the introduction of new product releases and their marketing is highly important, but also very hard to achieve.

Two persons from each company – a senior technology manager and the project manager – rated these four items on a seven-point Likert scale. For each item, the intra-class correlation coefficient was calculated, as shown in Table 4. As all the ICC scores were above 0.65 ($p<0.01$) (cf. Boyer and Lewis 2002, Boyer and Verma 2000), we were able to form a combined measure using the data from both respondents.[25] The factor analysis shows that all four items load on one factor. The Cronbach-alpha of this construct was .77, while the factor analysis explains 60% of the total variance.

Table 22: Intra-class correlation and factor loadings / improved capability to manage collaborative R&D processes

Items	ICC	p-value	Factor loading
The project helped us to improve our use of prototypes in collaborative projects.	.67	p < 0.01	**.64**
The project helped us to improve our release management in collaborative R&D projects	.65	p < 0.01	**.79**
Through the project, we learned to better divide tasks & responsibilities in collaborative R&D projects	.69	p < 0.01	**.79**
The project has improved our use of milestones in collaborative projects	.83	p < 0.01	**.87**
Average ICC	.71		

Two-way-mixed ICC, confidence interval 95%; Factor loading according to unrotated principal component analysis

6.3.4 Controls

Previous research suggests especially two inter-company relationship characteristics to impact learning outcomes on a general level. First, the effect of <u>earlier collaboration experience</u> with the partner on learning outcomes has been proven in numerous earlier research studies. In general terms, the development of relative absorptive capacity through collaboration – which leads to an increase in the capability to learn from future collaborations with the same partner – suggests that earlier partner-specific collaboration experience is positively correlated with inter-organizational learning. This view is supported by Simonin (99), who has investigated the effect of previous partner-specific experience on the effectiveness of transfer of tacit marketing know-how. Second, <u>knowledge similarity</u> between the partners has an impact on learning outcomes. On one hand it secures that the partners understand each other, forming the basis for a joint language (Lane and Lubatkin 1998). On the other hand, too similar knowledge bases may lead to a decrease in learning (Autio et al. 2000).

[25] For those cases for which only one answer was available, this answer was used.

Even though the focus of this study is on characteristics of the relationship – specifically inter-partner competition, complementarity of organizational knowledge bases, and inter-partner trust, it is necessary to control for certain company characteristics that have been previously shown to influence the success of knowledge transfer. First, the motivation to learn is suggested by earlier research to influence learning outcomes (Szulanski 1996, Kalling 2003). Second, we control company size in terms of net sales.

7 Results

The statistical technique used in this study is moderated regression analysis. The term moderator refers to a variable that influences the strength and/or direction of the relation between an independent and a dependent variable (Baron and Kenny 1986). The moderating effect is determined by introducing an interaction variable into the regression equation, as shown below for the example of an interaction between x_1 and x_2:

$$\hat{Y} = B_1x_1 + B_2x_2 + \ldots + B_nx_n + B_{n+1}x_1x_2 + B_0$$

A moderating effect is present, if the interaction is significant – independent on whether the main effects of the predictor and moderator themselves are significant. In order to be able to clearly interpret the interaction term, it is desirable that the moderator be uncorrelated with both the predictor and the criterion variable. (Baron and Kenny 1986)

Before entering them into the regression, all predictor variables were centered. This helps to reduce unessential multicollinearity, and allows for easier interpretation of the first-order regression terms: With centered variables, each first-order coefficient depicts the regression of the criterion on the respective predictor at the sample means of the other regression variables (Cohen et al. 2003).

Table 23: Means, standard deviations and correlations of the regression variables

	Variables	Mean	s.d.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
1.	Process learning	4.5	1.14										
2.	Motivation to learn from partners' R&D processes	0.0	1.56	0,37									
3.	Net Sales	0.5	4291	-0,33	-0,24								
4.	Earlier cooperation experience	0.0	2.05	0,22	0,19	-0,12							
5.	Organizational knowledge similarity	0.0	1.28	0,16	0,05	-0,03	0,18						
6.	Perceived competition	0.0	1.67	0,12	-0,08	0,02	0,03	0,11					
7.	Organizational knowledge complementarity	0.0	1.28	0,14	0,05	0,10	0,00	0,27	0,30				
8.	Interorganizational trust	0.0	1.22	0,34	0,22	0,02	0,31	0,18	0,01	0,22			
9.	Meetings	0.0	1.47	0,46	0,19	0,07	0,10	0,27	0,03	0,31	0,42		
10.	Transfer of people	0.0	1.25	0,53	0,17	-0,16	0,21	0,12	0,02	0,15	0,31	0,48	
11.	Written documents	0.0	1.34	0,42	0,27	0,03	0,14	0,23	0,03	0,27	0,41	0,63	0,51

Correlations greater than .23 are significant at $p < 0.05$; correlations greater than .29 are significant at $p < 0.01$

To detect essential multicollinearity problems, we calculated the tolerance values, which were all well above the critical threshold of 0,1 suggested by Hair et al. (1992).

Table 23 presents the means, standard deviations, correlations and two-tailed significances of the variables. Additionally, the correlations of the proposed moderators with the criterion and the predictor variables are relatively low, the highest being 0.42.

Table 24: Results of the moderating regression analysis

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Motivation to learn from partners' R&D processes	.19*	.23*	.24*	.24*	.22*	.22*	.20*
Net Sales	-.26**	-.23*	-.24**	-.29**	-.23*	-.26**	-.26**
Earlier cooperation experience	.03	0.02	0.02	.05	.06	.05	.04
Knowledge similarity	.00	-0.2	-.09	-.05	.00	-.03	.00
Interorganizational trust	.09	.09	.07	.06	.08	.05	.08
Knowledge complementarity	-.03	-.06	-.05	-.06	-.02	.03	-.05
Perceived competition	$.13^{+}$	$.14^{+}$	$.12^{+}$	$.15^{+}$	.12	.11	$.15^{+}$
Meetings	.26*	.31*	.25*	.27*	.28*	.27*	.27*
Transfer of people	.29**	.27*	.29**	.29**	.32**	.30**	.32**
Written documents	.03	.02	.08	.06	-.03	-.02	.04
Competition X Meetings		.19*					
Competition X Transfer of People			.26**				
Competition X Documents				.22*			
Org. knowledge complementarity X Meetings					.21*		
Org. knowledge complementarity X Documents						$.15^{+}$	
Trust X Transfer of People							$-.14^{+}$
Adjusted R^2	.40	.42	.46	.44	.40	.39	.39

Dependent Variable: Improved Capability to Manage Collaborative R&D Processes

$^{+}$ p<0,1 *p<0,05 **p<0,01

In order to test the Hypotheses 1-3, we constructed a regression model with improved capability to manage collaborative R&D processes as dependent variable.

Hypothesis 1a, 1b and 1c state that competition would positively moderate the effect of all three types of knowledge transfer mechanisms on process learning. As shown in Table 24, the regression analysis suggests that competition has a significant moderating effect on meetings (model 2), the transfer of people (model 3), and written documents (model 4). The highest correlation and significance can be found in the effect of competition on the transfer of people. Thus, Hypothesis 1 gets full support.

Hypotheses 2a and 2b state that organizational knowledge complementarity positively moderates the effect of meetings and written documents on process learning. When examining models 5 and 6, we find a significant positive moderating effect of organizational knowledge complementarity, thus supporting hypotheses 2a and 2b. Thus, Hypothesis 2 is fully supported.

Hypothesis 3 states that inter-organizational behavioral trust moderates the effect of transfer of people on process learning. Model 7 shows a significant, but negative moderating effect. However, the overall influence of trust – including the negative moderating effect on the transfer of people is still positive.

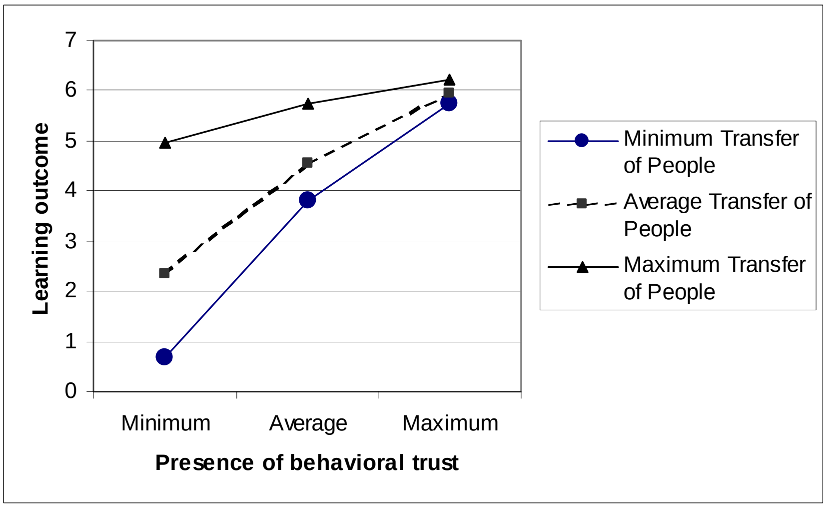

Figure 12: The moderating influence of trust on transfer of people

As Figure 12 clarifies, the positive effect declines, as transfer of people is increased. The figure presents the effect of behavioral trust and transfer of people on process learning, with all other variables in the regression having their average value of the sample. The results thus support Hypothesis 3. The Results are illustrated in Figure 13.

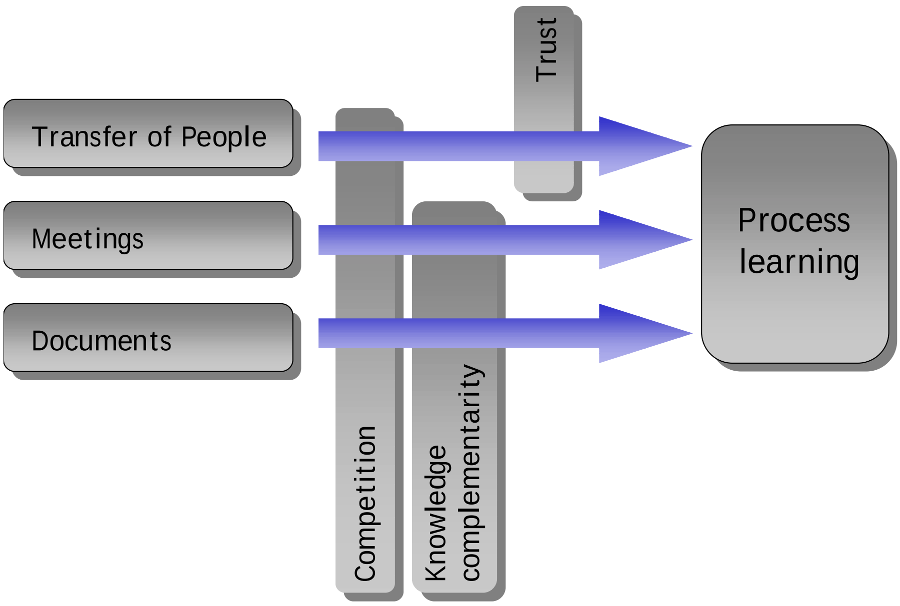

Figure 13: Framework of the research

8 Discussion

Previous research has shown that the alliance characteristics competition, organizational knowledge complementarity and trust influence inter-organizational learning. While our study supports this view, it shows that specific knowledge transfer mechanisms work differently depending on these relationship characteristics. The findings are supported by and extend previous research suggesting that formal and informal communication mechanisms are affected differently by contingency factors such as uncertainty (Tushman 1979), and differ in effectiveness depending on how alike the organizational mind sets of two communicating organizations are (Tushman and Scanlan 1981).

The results show that competition affects the effectiveness of all three groups of knowledge transfer mechanisms – meetings, documents and transfer of people in a positive way. Previous research provides diverging views on the effect of competition on knowledge sharing: While some researchers argue that competition hinders the free flow of knowledge (e.g. Kale et al. 2001), others promote the view that competition stimulates the collaborating parties to focus on learning through the creation of learning races (Child 2001, Dussauge et al. 2000). These learning races occur especially in situations, where the collaborating companies feel that they are able to reach private benefits through this collaboration, that are not available to their partner (Khanna et al. 1998). The findings of this research suggest, that the chance to improve their R&D process through process learning constitutes a high enough private benefit for the collaborating companies to engage in learning races.

Organizational knowledge complementarity seems to affect only meetings and documents – the knowledge transfer mechanisms through which mainly organizational knowledge is exchanged. The transfer of people, in contrary, seems to be unaffected by knowledge complementarity. An explanation for this result is, that through the transfer, people exchange tacit knowledge and personal experience that was not available to the organizational knowledge base, and the existence of which was not known to the organization. This view is supported by previous research (Nonaka et al. 2000), and conforms with Pautzke's (1989) notion of organizational meta-knowledge, i.e. knowledge about the existence of knowledge within or outside an organization.

In respect to the influence of trust on the effectiveness of transfer of people, the study shows a declining positive effect. In other words, while trust and the transfer of people contribute positively to the learning outcome, the positive effect of inter-organizational trust decreases with an increasing transfer of people, or vice-versa. An explanation for this may lie in the role of inter-organizational trust in collaboration: Through reducing the fear of opportunistic behavior, trust fosters inter-organizational learning (Kale et al. 2000). Another way to reduce a partner company's fear of opportunistic behavior is openness and communication. The positive effect of intense communication behavior on the ability of virtual teams to cope with problems and conflict has been documented in previous research (Järvenpää and Leidner 1999). Thus it is well possible that the influence of trust will be highest in situations, where the transfer of people is used only to a little extent, and will decrease with an increased communication. This result also supports the notion of "swift trust", which occurs in temporary, often virtual teams (Järvenpää and Leidner 1999, Meyerson et al. 1996).

9 Limitations and Future Research

This study is subject to a number of limitations. The first, and strongest limitation arises from the general limitations of moderated multiple regression analysis, and relates to the fact that, under certain circumstances, the hypothesis of a moderating effect is rejected too easily. The factors that lead researchers to erroneously dismiss moderated relationships are nonrandom sampling, imperfect construct reliability, low sample size, and predictor intercorrelations (Aguinis 1995). The latter factor has been mitigated in this study through centering the predictors. The sample size of this study lies somewhat below the suggested samples size of 120. The reliability thresholds used generally in management research pose another limitation, since they do not correspond to perfect reliability (i.e. a Cronbach alpha of 1) (Aguinis 1995). A second limitation concerns cultural differences. It has been argued that knowledge creation processes are highly sensitive to the pervasive effect of culture (see, for instance, Glisby & Holden, 2003; Holden, 2001, Smeds et al. 2001). Third, the link between improvements in collaborative R&D practices and innovativeness of an organization was beyond the scope of our study. Thus, a future research project could explore, for instance, how the standardization of collaborative R&D processes affects the emergence of radical, as opposed to incremental innovations in collaborative R&D (Benner & Tushman, 2002). Fourth, the scope of the study is limited to the telecommunications industry in general, and to R&D collaboration between network equipment manufacturers, their suppliers, and network operators in particular. This may weaken the applicability of our findings in other industrial sectors.

Especially the findings concerning inter-partner trust open an interesting avenue for further research: By investigating the emergence and evolution of collaborative R&D practices over time in a longitudinal research setting, the possible changes in inter-partner trust over time could be taken into account, and their influence on the different knowledge transfer mechanisms investigated. Second, the effect of the control variables in this study – especially earlier cooperation experience – on knowledge transfer mechanisms seems to be worthwhile investigating.

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APPENDIX

The Business Process Simulation Method

The action research that part of this dissertation is based on used the SimLab Business Process Simulation Method, a method for process development, training, change management development of present systems and re-engineering of operations. Even though the technique applied in this study has been developed in Finland, simulation gaming is successfully used in a number of countries. Tsuchiya and Tsuchiya (1999) have found gaming/simulation to support the change of governing mental models and to create shared mental models among the participants. According to them, gaming/simulation fosters among other things: *voluntary learning*, *creation of a shared experience*, *raising turmoil as a prerequisite for critically assessing the validity of the governing mental model* and the *creation of a holistic view of the issue handled in the simulation.*

The reasons for choosing the business process simulation method for this study are twofold: First, the business process simulation method provides the action researcher with a very thorough understanding of the case project, within a short period of time. Through observing the interactions and comments of the project members during the simulation session, a first-hand experience of the issues in the case project is guaranteed. This grants the researcher a position close to having been project member of the case studied. In addition, during the model-building phase, numerous face-to-face interviews give the researcher access to opinions and insights that may not have been otherwise stated by the interviewees. Second, by participating in a simulation session, the participants – including researchers – participate in the exchange of tacit knowledge – knowledge that could not be transferred by simply interviewing the project personnel.

Business process simulation is a structured, directed and visualized discussion about the activities, tasks and information flows in a selected business process. When simulating R&D processes, real case projects are systematically 'talked through' in a process-oriented way to enlighten the reality in the process. The discussion is led by a facilitator, and supported by visual process models on big wall screens. The simulations raise both operative and strategic questions and learnings that can be utilized in successive projects.

The composition of the simulation team is critical for the validity of the simulation: ideally, all people involved in the project simulated should participate in the simulation, either as active players or as observers. In the simulation, the individuals' tacit knowledge is shared into tacit and explicit knowledge of the organization. Inter-functional, inter-level participation is necessary to include in the simulation the necessary tacit and explicit knowledge required for successful innovation.

In more detail, the practical realization of the business process simulation used in this study included the case projects' selection and a preliminary modeling phase that was conducted by the whole R&DNet – project team. The process steps for carrying out the simulation are depicted in Figure 14 below:

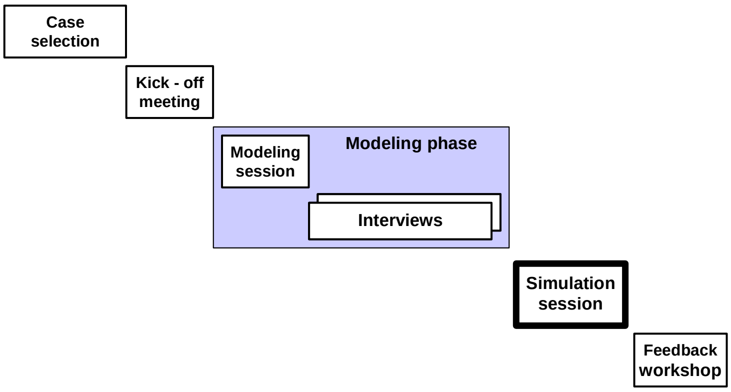

Figure 14: The Simulation Process

After the kick-off meeting, where the needs of the partner companies and the research team were shared, the next step was the modeling session, where coarse project models were constructed. The main objective was to reproduce the activities of the past project in chronological sequence, and to find the most important interdependencies between the activities. A simple technique of hand-written paper notes was found most flexible. After the modeling session, the coarse models were transferred into electronic form using flowchart software. The picture below has been rendered illegible due to confidentiality reasons.

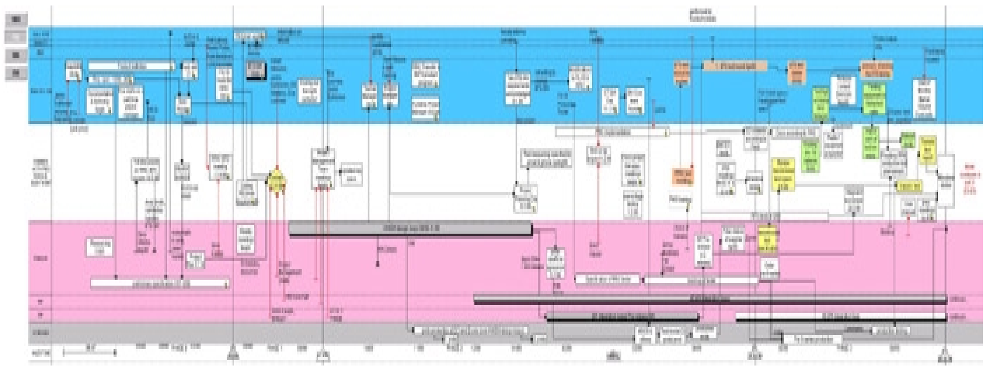

Figure 15: Process Flowchart

The next phase was to complete the project models. This was done by individually interviewing the project personnel. Notes were made during these interviews, backed up with audio recordings.

After the preliminary modeling and interviewing phases, the simulation sessions were arranged. During the sessions, the project members from both companies talked jointly through the projects in a facilitated way, activity by activity. Because most of the members had been working in the projects that were simulated in the game and thus possessed tacit knowledge about them, it was possible to return to the actual contexts, where different actions and decisions proved out to be failures or success factors. Finally, a debriefing workshop with the purpose of finalizing and disseminating the learnings from the simulation game session was held for each of the cases.

Questionnaire

TEKNILLINEN KORKEAKOULU
HELSINKI UNIVERSITY OF TECHNOLOGY

> Your answers will be handled strictly confidentially. The data will be used for research purposes only. No reference will be made to individual companies. The questionnaire has an identification tag only to make sure that we do not call you to ask you for the questionnaire, if you have already returned it.

Instructions:

- Fill in the first part of this page
- Choose a typical, finished R&D project which your company has run in cooperation with another company. The project should be somewhat familiar to you. Fill in the second part of this page about this particular case project.
- Then, please pass the questionnaire on to the manager of this project to fill out the rest of the questionnaire.
- **Please fill in the response coupon and send it back to us. THANK YOU!**

TECHNOLOGY EXECUTIVE PART

1. Please provide us with some background information about your company

Total net sales *(year 2000):* ______________ US$ Average R&D/sales-ratio during the last three years: ______________ %

Number of employees (year 2000): __________ Number of R&D projects over the last three years (approx.): __________

2. Next, we would need some information about your experience in collaborative R&D:

How many collaborative R&D projects has your company run over the last three years (approx.): ______________

What products did you mainly develop in these cooperations:
- ☐ New products in existing product families
- ☐ Platforms for new product families
- ☐ Breakthrough products, building up a new business

3. We would like to know how you manage R&D cooperation:

Do you have dedicated personnel for developing R&D cooperation? ☐ yes ☐ no

Do you centrally manage the portfolio of your R&D cooperation relationships? ☐ yes ☐ no

4. How true are the following statements?

	STRONGLY DISAGREE … STRONGLY AGREE
We have clear objectives for the development of our collaborative R&D process	1 2 3 4 5 6 7
We aim to learn about our partners' R&D processes in all our collaborative R&D projects	1 2 3 4 5 6 7
We monitor the performance of our collaborative R&D projects	1 2 3 4 5 6 7

Please answer the following questions concerning the case project you have chosen

5. Please characterize the relationship between your company and your partner company

How many R&D projects did you run with this partner altogether: (approx.) ______________

How many years have you already been collaborating: ______________

Taking all projects with this partner together, how many manyears did they take in your company (approx.): ______________

Does your company have an equity stake in your partner company (how many %?) ______________

Does your partner company have an equity stake in your company (how many %?) ______________

6. How true are the following statements?

	STRONGLY DISAGREE … STRONGLY AGREE	CANNOT TELL
The project has shown us unknown sources of knowledge that exist in our external environment	1 2 3 4 5 6 7	∆
The project has shown us unknown sources of knowledge that exist in our partner company	1 2 3 4 5 6 7	∆
The project has shown us unknown sources of knowledge that exist in our own company	1 2 3 4 5 6 7	∆
Cooperating with this partner has helped us to see our existing knowledge in a new context	1 2 3 4 5 6 7	∆
The project helped us to apply our knowledge to new situations	1 2 3 4 5 6 7	∆
The project helped us to improve communication between our own functional departments	1 2 3 4 5 6 7	∆
The project increased trust between our company's participating departments	1 2 3 4 5 6 7	∆
The project helped us to improve our use of prototypes in collaborative projects	1 2 3 4 5 6 7	∆
The project helped us to improve modularity in collaborative projects	1 2 3 4 5 6 7	∆
After the project our own departments co-operate more than they did before	1 2 3 4 5 6 7	∆
The project helped us to improve our release management in collaborative R&D projects	1 2 3 4 5 6 7	∆
The project has improved our use of milestones in collaborative projects	1 2 3 4 5 6 7	∆
In this project, we learned about our partner's R&D process	1 2 3 4 5 6 7	∆
We use this knowledge in our company's own R&D	1 2 3 4 5 6 7	∆
The project helped us to increase interaction between our R&D engineers and marketing people	1 2 3 4 5 6 7	∆
The project helped us to increase interaction between our R&D engineers and manufacturing people	1 2 3 4 5 6 7	∆
The project increased interaction between our company and our partner company	1 2 3 4 5 6 7	∆
The project increased personal friendship between us and the partner company	1 2 3 4 5 6 7	∆
The project increased mutual trust between us and the partner company	1 2 3 4 5 6 7	∆
Through the project, we learned to better divide tasks & responsibilities in collaborative R&D projects	1 2 3 4 5 6 7	∆
Our company's good reputation made it easier for us to find this partner	1 2 3 4 5 6 7	∆
If our partner had behaved opportunistically, their reputation in the industry would have suffered	1 2 3 4 5 6 7	∆
Cooperating with this partner improves our credibility as a R&D partner in the industry	1 2 3 4 5 6 7	∆

7. How true are the following statements?

	WITH SAME PARTNER (STRONGLY DISAGREE … STRONGLY AGREE)	WITH OTHER PARTNERS (STRONGLY DISAGREE … STRONGLY AGREE)
In this project, we learned from our partner ways to cooperate	1 2 3 4 5 6 7	1 2 3 4 5 6 7
We use this knowledge in other R&D cooperations	1 2 3 4 5 6 7	1 2 3 4 5 6 7
We use this knowledge in other **non**-R&D cooperations	1 2 3 4 5 6 7	1 2 3 4 5 6 7

END OF TECHNOLOGY EXECUTIVE PART

PROJECT MANAGER PART

This part should be filled in by the manager of the collaborative case project chosen on the first page.

8. What are your business areas?

☐ Network Operator ☐ Network Equipment Manufacturer ☐ Supplier to Equipment Manufacturer
☐ Other (please specify): ______________________

9. Please provide us with some background information about the project

Number of employees in your partner company (year 2000, approx.) ______________________
Number of persons involved in the project (approx.) ...... your company: ________ ...... both companies together: ________

10. Please provide us with some information about the product that was developed in the case project

What kind of product was developed in the project:
☐ Improvements of existing product families
☐ New product families
☐ Breakthrough products, starting a new business

Was the product developed a component / part of a larger product sold by your partner? .... ☐ yes ☐ no
Was the developed product a component / part of a larger product sold by your own company? .... ☐ yes ☐ no

11. How true are the following statements for your relationship with this partner?

	STRONGLY DISAGREE – STRONGLY AGREE
We and our partner firm are not sure how long our R&D cooperation relationship will last	1 2 3 4 5 6 7
We serve the same customers as our partner	1 2 3 4 5 6 7
We see the relation with our partner as a long-term relation, in which one must invest	1 2 3 4 5 6 7
In some markets, we are in direct competition with our partner	1 2 3 4 5 6 7
We assume that we will continue R&D cooperation after this project	1 2 3 4 5 6 7
We use the same suppliers for critical components as our partner does	1 2 3 4 5 6 7
We sell products that can substitute some of our partner's products	1 2 3 4 5 6 7
At some point in the future, our partner could become our competitor	1 2 3 4 5 6 7

12. On what organizational level are the following decisions made? (Tick △ if you cannot tell)

					CAN'T TELL
...in your own company:					
a) R&D project budget	☐ Top management	☐ R&D management	☐ Business unit management	☐ Project management	△
b) R&D project human resources	☐ Top management	☐ R&D management	☐ Business unit management	☐ Project management	△
...in your partner company:					
c) R&D project budget	☐ Top management	☐ R&D management	☐ Business unit management	☐ Project management	△
d) R&D project human resources	☐ Top management	☐ R&D management	☐ Business unit management	☐ Project management	△

13. How true are the following statements for both you and your partner?
(1=strongly disagree – 7=strongly agree, △=cannot tell, please answer both columns)

	OWN COMPANY (strongly disagree – strongly agree ?)	PARTNER COMPANY (strongly disagree – strongly agree ?)
The case project was run as separate functional tasks rather than a process	1 2 3 4 5 6 7 △	1 2 3 4 5 6 7 △
R&D designers and marketing people worked together on joint tasks	1 2 3 4 5 6 7 △	1 2 3 4 5 6 7 △
There was a predefined process for this project	1 2 3 4 5 6 7 △	1 2 3 4 5 6 7 △
R&D designers and manufacturing people worked together on joint tasks	1 2 3 4 5 6 7 △	1 2 3 4 5 6 7 △

14. What functions were involved in the project from both companies?

...in your own company:	☐ Project Management	☐ HW/SW Design	☐ Quality	☐ Finance / Controlling
	☐ Manufacturing	☐ Logistics	☐ Marketing	Other: ________
...in your partner company:	☐ Project Management	☐ HW/SW Design	☐ Quality	☐ Finance / Controlling
	☐ Manufacturing	☐ Logistics	☐ Marketing	Other: ________

15. What were the motives of your company for this collaborative project?

	NO MOTIVATION – STRONG MOTIVATION
We did not have enough R&D personnel to conduct the project alone	1 2 3 4 5 6 7
Our own technical skills were insufficient	1 2 3 4 5 6 7
We wanted to learn to co-operate with this partner	1 2 3 4 5 6 7
We wanted to teach our partner our R&D process	1 2 3 4 5 6 7
We wanted to learn about our partner's R&D process	1 2 3 4 5 6 7
We wanted to shorten the development leadtime of the product developed	1 2 3 4 5 6 7
We wanted to reduce our development costs	1 2 3 4 5 6 7
We wanted to increase our creativity	1 2 3 4 5 6 7
We wanted to create business for us	1 2 3 4 5 6 7
We wanted to share our skills to cooperate with our partner	1 2 3 4 5 6 7
Other: ______________________	1 2 3 4 5 6 7

16. What was the main reason for you to choose this partner?

____

17. In this project, what was your role in respect to your partner?

☐ Customer ☐ Supplier ☐ Co-Supplier ☐ Other: ______________________

18. How true are the following statements? STRONGLY DISAGREE — STRONGLY AGREE

Our partner has the reputation of having high technological skills 1 2 3 4 5 6 7
Our partner has the reputation of being a reliable cooperation partner 1 2 3 4 5 6 7

The agreement about the rights to utilize the outcome of the project was very **detailed** 1 2 3 4 5 6 7
The joint risk sharing agreement was very **detailed** 1 2 3 4 5 6 7
Our internal rules about what knowledge we share with our partner were very **detailed** 1 2 3 4 5 6 7

The agreement about the rights to utilize the outcome of the project was very **flexible** 1 2 3 4 5 6 7
The joint risk sharing agreement was very **flexible** 1 2 3 4 5 6 7
Our internal rules about what knowledge we share with our partner were very **flexible** 1 2 3 4 5 6 7

Our company's project members had extensive earlier cooperation experience with **our partner** 1 2 3 4 5 6 7
Our partner's project members had extensive earlier cooperation experience with **our company** 1 2 3 4 5 6 7
The project members from both sides have worked previously with each other 1 2 3 4 5 6 7

The project was characterized by…
…personal interaction between us and the partner at multiple organizational levels 1 2 3 4 5 6 7
…personal friendship between us and the partner at multiple organizational levels 1 2 3 4 5 6 7
…mutual trust between us and the partner at multiple organizational levels 1 2 3 4 5 6 7
…mutual respect between us and the partner at multiple organizational levels 1 2 3 4 5 6 7

19. When was the cooperation contract for this project signed? .... 1 2 3 4 5 6 7 △
(1 = before the project started – 7 = just before finishing the project, △= there was no contract at all)

20. How true are the following statements? STRONGLY DISAGREE — STRONGLY AGREE

The contract specified the cooperation process in great detail 1 2 3 4 5 6 7
In this project, informal agreements had as much or more significance as formal, signed contracts 1 2 3 4 5 6 7
The cooperation procedures were defined very flexibly 1 2 3 4 5 6 7
The contract facilitated the sharing of knowledge between us and our partner 1 2 3 4 5 6 7
Our company regularly monitored to which extent our partner met the goals specified in the contract 1 2 3 4 5 6 7
Our company had developed specific R&D procedures for the partner to follow 1 2 3 4 5 6 7
Our partner had developed specific R&D procedures for us to follow 1 2 3 4 5 6 7
We closely monitored the extent to which the partner firm followed the established R&D procedures 1 2 3 4 5 6 7
The R&D management capabilities of our partner were very similar to ours 1 2 3 4 5 6 7
Our company and our partner complemented each other's technical knowledge 1 2 3 4 5 6 7
Our company and our partner complemented each other's R&D management capabilities 1 2 3 4 5 6 7
The technical knowledge & skills of our partner were very similar to our company's skills 1 2 3 4 5 6 7
The use of prototypes was a major procedure of the project 1 2 3 4 5 6 7
The project has increased our use of prototypes 1 2 3 4 5 6 7
We used "quick & dirty" prototypes to drive the development process in this project 1 2 3 4 5 6 7
We tried to get the product developed completely right at the first try 1 2 3 4 5 6 7
During the project, there were spontaneous, informal meetings between both companies 1 2 3 4 5 6 7
Whenever some unexpected situation arouse, we worked out a new deal with our partner rather than holding each other to original terms 1 2 3 4 5 6 7
For this project, we used a R&D process that was defined jointly with our partner 1 2 3 4 5 6 7
Cooperating with this partner has helped us to see our existing knowledge in a new context 1 2 3 4 5 6 7
We were able to share with our partner cooperation procedures and processes 1 2 3 4 5 6 7

21. Did you have a project planning event to start the case project? ☐ yes ☐ no

If you had a Project Planning Event, who attended:

	People from earlier projects	**People from the starting project**
People from own company	☐	☐
People from partner company	☐	☐

If you did not have a Project Planning Event, how did you start your project: ______________________

22. Did you have a closing meeting, where lessons learnt from this project were summed up? ☐ yes ☐ no

If you had such a closing meeting, who attended:

	People from this finished project	**People from new projects**
People from own company	☐	☐
People from partner company	☐	☐

23. We would like to know, whether you and your partner were situated in different countries:
Your company was situated in: ____________ Your partner company was situated in: ____________

24. If the product development was cheaper than planned, who did get / would have got the savings? 1 =you, 7 =your partner) .... you 1 2 3 4 5 6 7 partner

25. How true are the following statements?

	WITH SAME PARTNER (STRONGLY DISAGREE – STRONGLY AGREE)	WITH OTHER PARTNERS (STRONGLY DISAGREE – STRONGLY AGREE)
In this project, we learned from our partner ways to cooperate	1 2 3 4 5 6 7	1 2 3 4 5 6 7
We use this knowledge in other R&D cooperations	1 2 3 4 5 6 7	1 2 3 4 5 6 7
We use this knowledge in other **non**-R&D cooperations	1 2 3 4 5 6 7	1 2 3 4 5 6 7

26. How true are the following statements?

	STRONGLY DISAGREE … STRONGLY AGREE
The project has shown us unknown sources of knowledge that exist in our external environment	1 2 3 4 5 6 7
The project has shown us unknown sources of knowledge that exist in our partner company	1 2 3 4 5 6 7
The project has shown us unknown sources of knowledge that exist in our own company	1 2 3 4 5 6 7
The project helped us to apply our knowledge to new situations	1 2 3 4 5 6 7
We were able to share with our partner useful R&D procedures	1 2 3 4 5 6 7
The project helped us to improve communication between our own functional departments	1 2 3 4 5 6 7
The project increased trust between our company's participating departments	1 2 3 4 5 6 7
The project helped us to improve our use of prototypes in collaborative projects	1 2 3 4 5 6 7
After the project our own participating departments co-operate more than they did before	1 2 3 4 5 6 7
The project helped us to improve our release management in collaborative R&D projects	1 2 3 4 5 6 7
The project has improved our use of milestones in collaborative projects	1 2 3 4 5 6 7
In this project, we learned about our partner's R&D process	1 2 3 4 5 6 7
We use this knowledge in our company's own R&D	1 2 3 4 5 6 7
The project helped us to increase interaction between our R&D engineers and marketing people	1 2 3 4 5 6 7
The project helped us to increase interaction between our R&D engineers and manufacturing people	1 2 3 4 5 6 7
The project increased interaction between our company and our partner company	1 2 3 4 5 6 7
The project increased personal friendship between us and the partner	1 2 3 4 5 6 7
The project increased mutual trust between us and the partner	1 2 3 4 5 6 7
Through the project, we learned to better divide tasks & responsibilities in collaborative R&D projects	1 2 3 4 5 6 7

27. How much were the following knowledge sharing means used in the collaborative project

(1=not at all,7=intensively; Please answer in both columns):	INTERNALLY	WITH THE PARTNER
Co-location	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Coaching by experienced members of earlier projects	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Corridor talk	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Job Rotation	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Process Consultants	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Contact lists of experienced people	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Process Development Workshops	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Preparation of test specifications	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Test result review meetings	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Teamwork within one function	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Teamwork across functions	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Brainstorming	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Design Review Meetings	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Prototype Review Meetings	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Milestone Review Meetings	1 2 3 4 5 6 7	1 2 3 4 5 6 7
E-Mail-Distribution Lists	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Newsgroups	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Technical Lectures	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Project Work Trainings	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Presentations of lessons-learned from other projects	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Lessons-learnt Reports	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Visual process maps	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Written process descriptions	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Reports from the final customer	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Final Reports	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Progress Reports during the project	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Meetings' Minutes	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Project Documentation	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Informal social events	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Components Data Bases	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Product Data Base	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Telephone conferencing	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Video conferencing	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Telephone (person-to-person)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
E-Mail (person-to-person)	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Company Intranet	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Project Intranet	1 2 3 4 5 6 7	1 2 3 4 5 6 7
Groupware (e.g. Lotus Notes, MS Exchange)	1 2 3 4 5 6 7	1 2 3 4 5 6 7

Has the project changed the way you use these tools and if yes, how?

____

Thank you for your valuable contribution!

Please mail the completed questionnaire to Helsinki University of Technology:
Helsinki University of Technology, Jan Feller, PO Box 9555, FIN-02015 HUT, Finland (tel. +358-50-3843954, jan.feller@hut.fi)