Towards a Systemic Model of Knowledge Integration

A Study in the Context of High-Tech Small and Medium Sized Firms

Jeroen Kraaijenbrink

Towards a Systemic Model of Knowledge Integration

A Study in the Context of High-Tech Small and Medium Sized Firms

Jeroen Kraaijenbrink

Graduation Committee:

prof.dr. P.J.J.M. van Loon (chairman)	University of Twente
prof.dr. R.A. Stegwee (promotor)	University of Twente
dr. A.B.J.M. Wijnhoven (assistant promotor)	University of Twente
dr. A.J. Groen (assistant promotor)	University of Twente
prof.dr. W. van Rossum	University of Twente
prof.dr. R. de Hoog	University of Twente / University of Amsterdam
prof.dr. H.-H. Schröder	RWTH Aachen (Germany)
prof.dr. J.C. Spender	Leeds University / Cranfield University (UK)
prof.dr. S.A. Zahra	University of Minnesota (USA)

Series title: CTIT Ph.D.-thesis Series
Series number: 1381-3617
CTIT Number: 05-77

Research School for Operations Management and Logistics

Centre for Telematics and Information Technology

This thesis is number D-79 of the thesis series of the Beta Research School for Operations Management and Logistics. The Beta Research School is a joint effort of the departments of Technology Management, and Mathematics and Computer Science at the Technische Universiteit Eindhoven and the Centre for Telematics and Information Technology at the University of Twente. Beta is the largest research centre in the Netherlands in the field of operations management in technology-intensive environments. The mission of Beta is to carry out fundamental and applied research on the analysis, design and control of operational processes

Cover design: JK
Printed by Febodruk B.V., Enschede, The Netherlands

ISBN: 90-365-2288-9

TOWARDS A SYSTEMIC MODEL OF KNOWLEDGE INTEGRATION

A STUDY IN THE CONTEXT OF HIGH-TECH SMALL AND MEDIUM SIZED FIRMS

DISSERTATION

to obtain
the doctor's degree at the University of Twente,
on the authority of the rector magnificus,
prof.dr. W.H.M. Zijm,
on account of the decision of the graduation committee,
to be publicly defended
on Friday 27 January at 16.45

by

Jeroen Kraaijenbrink

born on 18 February 1978
in Winterswijk, the Netherlands

This dissertation has been approved by:

prof.dr. R.A. Stegwee (promotor)
dr. A.B.J.M. Wijnhoven (assistant promotor)
dr. A.J. Groen (assistant promotor)

SUMMARY

"A book is a version of the world. If you do not like it, ignore it; or offer your own version in return."
Salman Rushdie (1947 -)

"Many books require no thought from those who read them, and for a very simple reason; they made no such demand upon those who wrote them."
Charles Caleb Colton (1780 - 1832)

In this study, knowledge integration (KI) is all the activities by which an organization identifies, acquires, and utilizes external knowledge. While crucial for organizations that develop new products, KI is a complex process that is not well understood in both research and practice. In research, we observe that the body of knowledge on KI is fragmented rather than accumulated and that there is no shared view on KI. In practice, we observe that it is difficult for practitioners to grasp the complexity and coherence of KI, which hinders KI problem solving.

To address these deficiencies in research and practice, this study develops a systemic KI model that supports the identification, explanation, and solving of KI problems that without such model would likely remain unidentified, unexplained, or unsolved. A systemic KI model is a conceptual 'thinking model' that shows the elements of KI and their relationships. Chapter 1 of this thesis defines seven characteristics of such a model, divided in three groups:

- three structural characteristics: a KI system consists of elements, boundaries, and an internal structure;
- two behavioral characteristics: a KI system shows differentiated patterns of activities and interchanges between parts of the system; and
- two control characteristics: a KI system is goal-directed and evolves in the course of time.

In order to develop such a model, this study answers three research questions.

The first research question reads '*What theoretical and empirical material for developing a systemic KI model can be derived from the current understanding of the KI process?*' It is split up into two subquestions: a) To what extent does the current KI literature provide sufficient theoretical and empirical material for developing a systemic KI model? and b) To what extent does an additional empirical study on KI provide the empirical material that is missing in the current literature?

Concerning research question 1a, a cross-disciplinary literature review is conducted covering a wide range of research fields, including organizational learning, knowledge management, information seeking, technology transfer, and research methodology. The results of this review are presented in Chapter 2, which invokes a little over 300 publications. The review demonstrates that on each of the seven characteristics there is substantial work done in terms of conceptualization and empirical research. However, there appear two

important gaps to be filled. The first gap concerns a lack of evidence for empirical patterning of KI activities. While some of the existing models draw on Parsons' version of social systems theory for the patterning of activities, empirical support is virtually lacking. Hence, additional empirical evidence is needed for the patterning of KI activities. The second gap concerns the problem that it would be impossible and undesirable to integrate all the reviewed material into one systemic model. This implies that a framework is needed for selecting parts of the collected material from the literature. It is argued that the choice for this framework should depend on the empirical patterning of KI activities.

The identification of these two gaps comprises the answer to RQ1a. Consequently, Chapter 3 reflects an attempt to fill these two gaps by means of an empirical study in the field of new product development (NPD) in high-tech small and medium sized enterprises (SMEs). The chapter follows a two-stage research approach, consisting of exploratory interviews with NPD managers of 33 high-tech SMEs and a survey amongst 317 high-tech SMEs. As a preparation for the survey, the 33 interviews provide a rich picture of how KI instantiates in the particular context of NPD in high-tech SMEs, a confirmation of the relevance of a systemic KI model, and examples of the language of SME practitioners concerning KI in their specific context. Based on the outcomes and experiences of the interviews, a questionnaire is developed in cooperation with an expert group of practitioners and academics that participated in the European project Knowledge Integration and Network eXpertise (KINX). After extensive pretesting with practitioners, this results in a questionnaire containing questions on 14 KI activities. An exploratory and confirmatory factor analysis of the results of the questionnaire provide indications for a four function model that shows remarkable correspondence with Parsons' four functions of adaptation, goal attainment, integration, and pattern maintenance. Although the fit of the empirical results and Parsons' four function model is not perfect, it is concluded that, combined with similar indications for this model in Chapter 2, Parsons' model should be used for the patterning of KI activities and as a framework for selecting relevant material from the literature. Hence, the two gaps that remained after the literature review are filled by the empirical study, implying that the first research question is answered.

After the answering of RQ1, the study continues with the second research question, which reads '*What systemic KI model can be derived from the framing of the gathered material into Parsons' social system theory*? The two subquestions are a) To what extent is Parsons' social system theory applicable to the KI context? and b) What systemic KI model can be derived from the framing of the gathered material into the applicable part of Parsons' social system theory? The answers to these questions are given in Chapter 4.

Because Parsons' theory is probably not well-known among some readers and has suffered a lot of criticism, Chapter 4 elaborates on Parsons' theory and some of its critiques. Consequently, in order to answer RQ2, that chapter summarizes Parsons' view with respect to the seven system characteristics and invokes the results of Chapters 2 and 3 to develop a systemic KI model based on Parsons' theory. The result of this endeavor is a preliminary version of a systemic KI model. Because of the preliminary nature of this model, it is not summarized here.

After the development of the preliminary version of the systemic KI model in Chapter 4, the final stage of this study is an assessment and improvement of the model. The research question guiding this final stage is: '*What is the soundness and relevance of the developed systemic KI model and how should it be improved?*' This question is subdivided into the following two subquestions: a) To what extent is the model sound and how can its soundness be improved? and b) To what extent is the model relevant for KI problem solving and how can its relevance be improved? Chapter 5 specifies the criteria against which the model is evaluated. Concerning the soundness of the model, these are consistency, precision, and correctness. Concerning the relevance of the model, these are manageability, fit with the problem, and timeliness.

With respect to the soundness of the model, it is concluded after a concise discussion that the model should be sufficiently consistent, precise, and correct for this stage of development by the systematic way in which it is built on literature, empirical data, and a model from social systems theory. This conclusion answers research question 3a.

The first two relevance criteria (manageability and fit with the problem) are assessed by confronting the model with examples of KI in practice. These examples are gathered by conducting 17 critical incident interviews in high-tech SMEs. These interviews yield 65 critical incidents of KI in practice. For both criteria, the seven characteristics of the preliminary model are assessed with these 65 incidents. Manageability is further decomposed into the criteria of simplicity, understandability, and practical usability. To assess and improve the manageability of the model, it is tried to reduce its complexity by omitting parts that do not seem necessary to model the variety of the 65 incidents. As Chapter 5 shows, the result of this assessment is not so much a model that is simpler, but rather a model that is better adjusted to practice. The assessment of the two remaining aspects of manageability – understandability and practically usable form – are postponed to further research.

After the assessment of the manageability of the model, a subset of the 65 critical incidents is used to assess and improve the model's fit with the problem. This is done by showing how the model could improve KI in a number of detailed KI incidents. It is concluded that although the model has potentially a good fit with the problem, further research is needed in which the model is used as an intervention rather than retrospectively.

Concerning the third relevance criterion, timeliness, it is argued that the model likely can be used before and during the emergence of KI problems. It is tentatively concluded that the model meets this final criterion. As such, this analysis provides an answer to the final research question.

The answers to the three research questions produce the outcome of this study: a systemic KI model that should support KI practitioners with the identification, explanation, and solving of KI problems that without such model would likely remain unidentified, unexplained, or unsolved. The model is presented in Chapter 6 and can be summarized as follows:

Elements of a KI system: A KI system consists of five types of elements: actors, information technologies, non-information technologies, KI activities, and knowledge, of which the latter is further decomposed into knowledge residing in actors, in information technologies, in non-information technologies, and in activities.

Boundaries of a KI system: A KI system can be gradually distinguished from its environment by means of the notions of interaction density and system barriers. Interaction is denser near

the kernel of a system and gets gradually less dense at its peripheries until the system dissolves in the environment. For each dyad of system elements there can exist various and different barriers that make interaction more difficult.

Internal structure of a KI system: A KI system consists of four functional subsystems (adaptation, goal attainment, integration, and pattern maintenance) that are, like the KI system itself, controlled by controlling organs. Additionally, a KI system also fulfills three knowledge functions (identification, acquisition, and utilization of knowledge) at both the level of the KI system and the level of subsystems.

Differentiated and patterned KI activities: KI activities are patterned around the four system functions. This means that KI activities are supposed to contribute more to one function than to another function without being exclusively attributed to that function. This also means that in order to fulfill a particular function, a pattern of KI activities is involved. The four patterns are: 1) Adaptive KI: the ability of the system to be receptive to changes in or introduced by external sources of knowledge; 2) Goal attainment KI: the ability of the system to set and achieve goals by identifying, acquiring, and utilizing knowledge from external sources; 3) Integrative KI: the ability of the system to develop into a coherent whole, by dissemination and integration of external knowledge in the system; and 4) Pattern maintenance KI: the ability of the system to create and maintain a stable and close relationship between elements of the system. Additionally, in the model, KI activities should be categorized according to knowledge functions. Knowledge functions are not associated with patterns of KI activities but should be used to categorize KI activities.

Interchange in a KI system: Interchanges take place between a KI system and its environment and within the system itself. They consist of an interchange of knowledge for other knowledge, or for generalized media (for example, money or power). Interchanges can be direct or indirect, the latter meaning that the interchange between two actors occurs via at least one other actor. Interchanges are to be seen as interchange systems that, like the functional subsystems, have their own controlling organ.

Goal-directedness of a KI system: KI activities and interchanges are directed by the goals of the actors that perform them. The controlling organs of the KI system, of its environment, of its subsystems, and of individual actors each may have their own goals. Goals can be conflicting and are formulated in interaction between actors rather than by individual actors or (sub)systems. Also, goals have intended and unintended consequences that mutually affect the achievement of other goals.

KI system evolution: KI systems evolve, or learn, in the course of time. Learning consists of a cognitive part and a behavioral part and can take place within functional subsystems (functional learning) and between functional subsystems (interfunctional learning). Finally, systems also can learn to learn (deutero learning).

Together, these seven characteristics comprise a systemic KI model that shows the complexity and coherence of KI in practice and that appears to be able to support the identification, explanation, and solving of KI problems that are less likely to be identified, explained, and solved without the model. The limitations to this model and its implications are discussed in the final section of Chapter 6.

Acknowledgements

"It is a miracle that curiosity survives formal education."

Albert Einstein (1879 - 1955)

"Human beings, by changing the inner attitudes of their minds, can change the outer aspects of their lives."

William James (1842 - 1910)

Realizing that this part of the thesis is perhaps the only part that is read by most readers, has led me to think about it over and over again. How to start? What to write? Whom to thank? How many confessions to include? How to write it without too many clichées? After staring too long at my computer screen and trying to escape into listening to too many conversations in the corridor I finally gave up on these questions and decided just to start writing.

The Project

A bound pile of paper like this does not come into being instantly. In the case of this thesis, it took almost four years from its very beginning to me trying to find the first mistake in the final printed version. The idea of pursuing a PhD must have occurred to me during the research done for my master thesis Industrial Engineering & Management. At the end of 2001, I thought it might be interesting to continue my life at the university; or, at least to continue doing research. I passed on this idea to my then supervisor, Robert Stegwee, and fortunately, he was not unhappy with it. He informed me about some vacancies for PhD positions which did not seem very interesting to me. A little later he found another vacant PhD position, based on a project proposal written by Fons Wijnhoven. The project was entitled 'An information market service for SME knowledge sharing expertise' and it was associated with a European project called Knowledge Integration and Network eXpertise (KINX)[1]. Not knowing anything about knowledge integration, information markets, networks, and SMEs, I applied to this position. Some conversations, formalities, and months later, on 1 February 2002, I worked my first hour on this project.

As can be inferred from the difference between the title of the project and the title printed on the cover of this book, the focus of the research has somewhat changed. Initially, the objective was to develop business models and process models for portals that could support knowledge integration (KI). After exploring the literature and practice, we realized that the current state of knowledge was not ready for this. An important lacuna concerned the current knowledge on KI. There was a lot written on KI, but it was hard to make sense of it. Our simple assumption was that when we want to support KI with a portal, we first should know what KI is like. As we could not infer this from the current literature, we decided to change the focus of the research from business and process models of portals to a conceptualization of KI. The result can be found in the pages underneath this one.

[1] This PhD project was partly funded by the KINX project, No. G1RD-CT-2002-00700

The Process

During the past four years many people outside the academic world have asked me one similar question: How on earth can you spend four years on one project? Without intending to fully answer this question, it is perhaps interesting to illuminate four phases of a cycle that kept me continuously busy the last years.

First of all there is confrontations. These are basically all communications with other people about the project. The very first confrontation was me reading the project proposal and talking to my future promotors. Later on, numerous confrontations have occurred with promotors, advisors, peers, reviewers, and colleagues. Common to each of these confrontations was that they have brought something new and unexpected into my project, such as a new idea, a comment, or a problem that I did not see. These confrontations mainly led me to rethink what I had done so far, which is where we enter the next phase.

The next phase is confusion. Usually, after a confrontation I was confused, not knowing how to deal with the new ideas or comments, or how to solve the problems that were mentioned during the confrontation. This phase usually already started during the confrontation by me pondering in silence, not answering questions and looking confused. After the confrontation it went on when I walked back home, looking but not seeing, and during the evenings, hearing but not listening to my wife (Caroline, I'm sorry about that). Particularly during the nights, this phase was very effective in keeping me awake. I guess that during these phases of confusion I worked hardest and was least successful. But fortunately, there was always a next phase.

The next phase is one of construction. Out of my confusions there were sudden feelings of euphoria when I had a 'Eureka moment' or an 'Aha-Erlebnis' in which I found a way to deal with the ideas or comments, or found a solution to a problem. At the most unexpected and strangest moments I could run for a pen and paper, writing as fast as possible, but not fast enough, in handwriting that, afterwards, even I had difficulties reading it. When I look back now, I think that none of these moments occurred at the office. Rather they seemed to concentrate around 4 o'clock in the morning when I was most unwilling to run for a pen and paper.

After the construction phases, there came phases of confidence. In these phases I got more and more confident that the solution that I found was the right one, or at least a very good one. During these phases I could feel happy with myself, being proud that I found such a fantastic solution. Being on top of the world, I could not imagine anymore that I did not see the solution before, and that I had needed so much effort to find it. Even more, I sensed how stupid the rest of the world was not to think of the solution. Also, I usually was sure that this was the final problem that had to be solved. Fortunately, these moments lasted only until the next confrontation took place in which I landed back on earth finding out that more confusion was to come.

As you see, pursuing a PhD can easily keep you busy day and night, four years long by a continuous cycle of confrontation, confusion, construction, and confidence. Whether I am the only one going through these cycles, I don't know. The fact is that they were there, sometimes taking long, sometimes taking only very short. The lesson? Perhaps that a confrontation a day keeps vanity away.

The People

The writing of this thesis took not place in isolation. Although I pressed the keys on the keyboard, many people have contributed to the realization of this thesis. Hoping not to painfully forget somebody, I take the risk of mentioning their names.

First of all, I'd like to thank my promotor, Robert Stegwee, and my two advisors, Aard Groen, and Fons Wijnhoven. Robert, while I found out that exactly none of our appointments went as I had planned, they were fruitful, without exception. Thank you for your critical attitude, nice way of commenting, and the trust you showed at the final stage of my project. Aard, I am glad that you did not convince me of the relevance of Parsons' theory. If you would have convinced me before I found it out myself, I believe we never would have had the interesting discussions on our different interpretations and use. Thank you for advising me. Fons, thank you for being annoyingly nitpicking. I am not aware of any advisor who is so critical, dedicated, stimulating, and enthusiastic as you have been during the past four years. While our confrontations could be fierce, I hope many others will benefit from your qualities. Also, I'd like to thank Wouter van Rossum at this place for his contribution to my project. Wouter, thank you for your advice to narrow down and be more concrete and specific. Although, looking at this thesis, I don't think I fully followed your advice, your contribution was vital.

During my PhD project, I have not found anybody else who had the challenging luxury of dealing with four supervisors. Of course, it was totally impossible to meet you all at the same time. Despite of your completely different backgrounds I was constantly surprised about the lack of conflicting demands you have put on me. Thank you for supervising me.

I also like to thank the members of the BIK/BIS/OIBIS/IT&M/IS&MC/ISMC/ISCM[2] department. Adri, Alea, Arjen, Boriana, Celeste, Chintan, Christiaan, Dennis, Diana, Eveline, Gerard, Jeffrey, Jos, Kees, Margreet, Marian, Mehmet, Michel, Peter, Reza, Svetlana, Theo, Ton, and Xiuzhen, thank you for being good colleagues and making it pleasant for me to go to the office each day again. Boriana, Mehmet, and Michel, thank you for creating a fruitful team spirit amongst the four of us and for being my peers with whom I could discuss any topic at any moment. Also, I'd like to thank you for your efforts to realize an office with walls and a wall with colorful post-it notes. Your efforts have surely improved the quality of my work. Boriana, thank you for sharing a room with me for two years, for lending me your books, for having an even messier desk than me, and for sharpening my thinking on modeling. Also, thank you for calling me 'not so asocial after all' in your own thesis. Mehmet, thank you for learning me more about methods and cognitive psychology, for being critical to everything, for joining me at the very first conference I went, and for learning us more about Turkey. I wish you all the luck with finishing your own thesis. Michel, thank you for sharing your interest in research philosophy and sociology and for commenting with me on the rest of the world. Also, I'd like to thank you that you sometimes stopped talking. Of course, some day you will find out that Giddens' theory is inferior to that of Parsons, but until then: best of luck with finishing your own thesis.

[2] By including all the names that have been assigned to our department, I hope I cover all the people that were working at the department during the past four years

There are many more people that contributed to this thesis. I'd like to mention the participants of the KINX project who supported me with conducting my empirical research, with sharpening my ideas, and with giving me the opportunity to work in an international project. I would like to particularly thank Hans-Horst Schröder, Antonie Jetter, Dina Franzen, Hannah Zaunmüller, Aharon Hauptman, Yoel Raban, Doron Faran, Charo Elorrieta, and Juan Pedro Lopez for the intensive cooperation we had during the three years of the project. I also like to thank Niels, Ronald, Jochem, and Rudi, our student assistants, for helping me calling over 400 companies and asking them to fill out our survey. Considering our response rate, you have done a great job. Also, I would like to mention the respondents of all interviews and the survey. Without your input, this research would have been impossible. I hope I have spent your time well and that you will somehow benefit from my research, be it yesterday, today, tomorrow, or at any later moment in your career. Marco Strijks (Syntens), thank you for your efforts in organizing a workshop with me. Hans Roosendaal and Paul van der Vet, thank you for discussing my research while it was still in an early stage. Shaker Zahra and JC Spender, thank you for reviewing my earlier work and for giving me a boost of motivation to continue my research. Anonymous reviewers and editors, thank you for your feedback and suggestions. Peter Geurts and Pieter Terlouw, thank you for helping me to find my way in the overwhelming amount of numbers and figures that SPPS and LISREL can produce. SPSS, thank you for providing me with an overload of material to give hilarious presentations about your Data Entry Module. Marco and Vincent, our system administrators, thank you for supporting me during one of the most stressful periods of my PhD. The every day excitement of testing whether my online questionnaire was still working must have taken you away from more interesting things. Also, I would like to thank the persons who have explicitly solicited to mention their names in this book. For whom this concerns, I am honored that you want to be mentioned. I hope this will do.

Finally, I must show all my gratitude, respect, and love to the most important person in my life. She has created the environment that allowed me to write this thesis. Caroline, thank you for regularly pulling me away from the sometimes strange world of academia and keeping me in touch with the more important aspects of life. Also, thank you for making me take days off and being my reason to come home every day. I admire your persistent efforts and patience to discover the real me and the support that you have given during the discoveries. I really hope that our future plans become a reality. You mean more to me than anybody has ever done.

Jeroen Kraaijenbrink

Enschede, 19 December 2005

Table of contents

List of Abbreviations

AGFI:	Adjusted Goodness of Fit Index
CIT:	Critical Incident Technique
CO:	Controlling Organ
GFI:	Goodness of Fit Index
INK:	Institute Dutch Quality
ISIC:	International Standard Industrial Classification
ISO:	International Standardization Organization
IT:	Information Technology
KF:	Knowledge Function
KI:	Knowledge Integration
KINX:	Knowledge Integration and Network eXpertise
KM:	Knowledge Management
KMO:	Kaiser-Meyer-Olkin (measure of sampling adequacy)
LSE:	Large Sized Enterprise
MTT:	Methods, Techniques, and Tools
NPD:	New Product Development
OMIS:	Organizational Memory Information System
R&D:	Research and Development
RQ:	Research Question
SF:	System Function
SME:	Small and Medium-sized Enterprise
TS:	Target System
VP:	Vice President

CHAPTER 1: INTRODUCTION

"Causal thinking has been used in science for such a long time and, in certain fields, with such success that it is almost generally considered as the scientific thinking, although it may well be only a subvariety of it. Relational thinking is so firmly rooted a habit that the transition to system thinking is at least as difficult as the transition from a three-dimensional to a four-dimensional geometry"

Angyal (in Emery, 1969: 29)

"In natural science we look down for explanation, expecting that physiology will account for psychological processes, and biochemistry for physiological processes. In social science, however, our first search should be at the more complex system level"

Katz & Kahn (1979: 4)

1.1 Motivation and Objective

In a time where the notion of organizational networks seems to take over the notion of single organizations (Castells, 1996; European Commission, 2002b; Knight, 2002; Powell, Koput, & Smith-Doerr, 1996), the image of a lonesome inventor developing innovative new products is not adequate anymore – if it has ever been. Truly, even Edison would not have invented the light bulb without extensive cooperation with other organizations. A key possession that Edison needed from these organizations was particular knowledge that he did not possess himself (Hargadon, 2003; Hargadon & Douglas, 2001). This still applies to current organizations: they need external knowledge to be innovative (Bougrain & Haudeville, 2002; Cohen & Levinthal, 1990; Howells, James, & Malik, 2003; Hummel et al., 2001; Von Hippel, 1988). Important categories of knowledge they need are customer/market knowledge, such as market trends and customer requirements; technological knowledge, such as properties of materials and design concepts; and organizational knowledge, such as machine capacities and operations management (Allen & Cohen, 1969; Ellis & Haugan, 1997; Faulkner & Senker, 1995; Olson et al., 2001). Organizations obtain this knowledge from a range of sources, including their customers and suppliers, universities, and the Internet (Julien, 1995; Kraaijenbrink, 2005a; White, Bennett, & Shipsey, 1982).

Accepting Schumpeter's (1934) claim that innovation is making new combinations, it is not surprising that organizations need external knowledge to be innovative. This claim suggests that innovations occur when existing and new knowledge is integrated and this results in, for example, a new product. Since knowledge is continuously changing and depreciating (Argote, Beckman, & Epple, 1990), organizations cannot possess all the required knowledge themselves. This implies that the effective integration of external knowledge is a significant success factor for innovation (Rothwell, 1994), which is nowadays recognized by a majority of companies in Europe (Murray & Myers, 1998). This process of *knowledge integration* (KI) is the focal subject of this study. For the moment, we define it as *all the activities by which an organization identifies, acquires, and utilizes external knowledge*. As will be explained in the following pages, this thesis will further refine and define this process by developing a conceptual model of it.

Amongst the various types of organizations, the dependency on external knowledge applies in particular to high-tech manufacturing small and medium sized enterprises (from here on called 'high-tech SMEs') (Atherton, 2003). Put simply, these are companies with up to five hundred employees designing and/or manufacturing technologically complex products, mostly for other organizations. Besides their sheer size, SMEs are characterized by having their ownership and management in the same hands; by often being family-owned; by targeting for a niche rather than a dominant position in the market; and by lacking formal management structures (European Commission, 1996). Whereas SMEs possess advantages like flexibility and responsiveness, they do not possess the power, people, and resources that large enterprises possess (Rothwell & Dodgson, 1994; Vossen, 1998). This makes them highly dependent on other organizations. *High-tech* SMEs distinguish themselves from other SMEs by employing more scientific and technically qualified people; by facing considerably higher rates of product obsolescence; by investing larger sums in research and development; by focusing more on developing new products from new technology; and by relying more on rapid, efficient new product introductions (Clark & Wheelwright, 1993; Jassawalla & Sashittal, 1998; Ramesh & Tiwana, 1999). Typical industries in which they operate are electrical machinery, precision instruments, and pharmaceuticals (OECD, 2001). Within these industries, SMEs make up for 99 % of all companies in Europe (European Commission, 2002a). Considering the importance of the new product development (NPD) process to high-tech SMEs, the knowledge intensive nature of this process and the dependence on external sources of knowledge in this process, KI is of crucial importance for high-tech SMEs.

Although KI is thus crucial to high-tech SMEs, the numerous governmental initiatives to support them in this area are an indicator that KI is not easy for them (Bessant, 1999; Bougrain & Haudeville, 2002). For example, governments provide subsidies, give training, found knowledge-brokering institutes and websites, and support collaboration between SMEs and research institutes (Jetter et al., 2005). On a European level, this kind of support has been central to the Fourth, Fifth, and Sixth Framework Program and will continue to do so in the Seventh Framework Program (http://www.cordis.lu/fp7). On a national level, we see similar initiatives within each country of the European Union. In the Netherlands, for example, the relevance of the topic has been underlined by the grand introduction of an 'innovation platform' which is responsible of improving the innovative performance of Dutch companies by a focus on knowledge valorization and knowledge use (AWT, 2003; AWT, 2004). Given this relevance of KI to NPD in high-tech SMEs and the apparent difficulty that these companies have with KI, we have chosen to focus this study on the empirical field NPD in high-tech SMEs.

When we look in more detail at the KI process, we can start to understand why it is not easy to effectively integrate knowledge. For example, KI involves people with very different tasks and competences, including research and development, marketing, and manufacturing (Griffin & Hauser, 1992; Olson et al., 2001; Song, Montoya-Weiss, & Schmidt, 1997). The substantial differences in the knowledge these people possess make that integrating their knowledge can be very challenging. Also, KI requires a number of very different activities. For example, the fact that useful knowledge can be diffused all over the world in companies and industries of which the organization that needs it is unaware, asks for activities to define what knowledge is useful and activities to find it. This can be very challenging (Leckie, Pettigrew, & Sylvain, 1996; Taylor, 1968). Also, knowledge is usually not simply a package that can be sent by mail or in some electronic format. Rather, it is more common that it requires extensive collaboration between the source and the recipient to obtain it (Groen et al., 2002; Ramesh & Tiwana, 1999). Finally, using the knowledge within an organization and applying it also can be challenging. It requires, for example, activities for retention (Szulanski, 1996) and absorption (Cohen & Levinthal, 1990; Zahra & George, 2002).

Although these activities already are a challenge in themselves, the challenge even increases when we realize that the activities are highly interdependent. For example, to apply external knowledge you also need to find it and acquire it. On the other hand, simply finding and acquiring knowledge does not automatically mean that you also can apply it; this requires additional activities, like transforming the knowledge to a usable form. Since these activities thus are highly interdependent in practice, managers need information as to how and why these activities are interdependent in order to be able to manage and control KI in their organizations. Currently, however, SMEs' managers lack this kind of information; they do not have a systematic overview of the complexity and coherence of KI (Kraaijenbrink, Groen, & Wijnhoven, 2005). When managers do not have such overview, they can try to affect parts of KI but without being able to estimate the effect of their actions on KI as a whole. As a result, their attempts to solve KI problems and improve KI can be without effect or even counterproductive (Okhuysen & Eisenhardt (2002).

The proposition of this thesis is that a *systemic KI model* will provide the overview of KI that is currently lacking and hindering KI problem solving. Put simply, a systemic KI model is a conceptual model of KI that shows how KI is a connected whole of interrelated people, technology, activities, and knowledge. As such, a systemic KI model can provide a manager with the overview that is needed to manage and control KI in his[3] organization. We believe that such a model is a necessary and complementary means for improving KI next to existing initiatives such as those mentioned above. How such model will contribute to the improvement of KI is explained in detail in Subsection 1.3.1.

When we look in the literature, a systemic KI model is currently not available. As we discuss in more detail in Subsection 1.3.2 and in Chapter 2, there is much known about parts of KI, but this has not accumulated into a coherent systemic model that shows how these parts are related. The objective of this study is to fill this gap in the literature by developing a systemic KI model. Before we explain in more detail why and how such model is a contribution to practice and theory, the next section first elaborates on the question as to what it means to develop a systemic KI model. This is done by characterizing KI as a system (Subsection 1.2.1) and by specifying the type of model a systemic KI model is (Subsection 1.2.2). The reader familiar with systems theory might want to skip Subsection 1.2.1.

1.2 Targeted Outcome

The notion of a systemic model roots in systems thinking. The credo of systems thinking is that the whole is more than the sum of its parts. This is because "[...] interaction among the parts can be understood only through laws of interaction that are not purely deducible from

[3] Wherever we use the term 'he' or 'his' without referring to a particular person, it can be replaced with 'she' or 'her'.

a knowledge of the attributes of the parts (units) alone" (Dubin, 1978: 265). Systemic research approaches can be found in various research disciplines under labels including system science, system theory, general system theory, systems research, and cybernetics.

Systems thinking differs substantially from the mainstream explanatory research and is even claimed to require a complete shift of mind (Emery, 1969; Senge, 1990). Also, systems thinking has been criticized for a long time, for example for being a myth, being too vague, ignoring the particular, being speculative and untestable, and being an ideology rather than a science (Lilienfeld, 1978), which may be reasons why it is currently out of fashion (Skyttner, 1998). Exactly because systems thinking is different from mainstream research, is being criticized, and is currently out of fashion, it is necessary to elaborate rather extensively on the key notions of systems thinking. On the following pages we will step-by-step specify the type of system under study (Subsection 1.2.1) and the type of model that we aim to develop (Subsection 1.2.2). Subsequently, Section 1.3 will discuss how such model can provide a practical and scientific contribution to KI.

1.2.1 On KI as a System

As Ackoff puts it "[...] we can define a system broadly and crudely as any entity, conceptual or physical, which consists of interdependent parts" (in Emery, 1969: 332). What this means in more detail and in the context of KI, is discussed below. The subsection starts with a characterization of systems thinking as an alternative to 'relational thinking'. Thereafter, the subsection gradually outlines the character of a KI system by categorizing it respectively as an open system, a complex system, a social system, and an aspect system. The subsection ends with a short note on the type of interconnections between system elements that are considered in a KI system.

Systems Thinking

One of the first references to systems thinking as an important way of thinking for research is made by Angyal in 1941 (Emery, 1969). Angyal compares systems thinking to relational thinking of which the latter is core to explanatory research. Relational thinking considers the direct relation between two and only two elements. In a system, however, "[...] the members are, from the holistic viewpoint, not significantly connected with each other except with reference to the whole" (Emery, 1969: 22). Angyal describes the difference between systems thinking and relational thinking as follows:

> "*In the recent past there has been much rather inconclusive discussion concerning the possibility of two different processes of knowing: explanation and understanding. I am referring here to the discussion of the problem, erklärende und verstehende Psychologie. The difference between the two concepts, as they have been used in the aforementioned discussion, is probably that explanation refers to relational thinking, understanding to system thinking. Relational thinking aims at the establishment of the direct connexion between two objects. For instance, in the study of causation one has to find for member a (effect) a second member b (cause) with which it is necessarily connected. In causal research the task is to single out from a multiplicity of data pairs of facts between which there is a necessary connexion. In system thinking the task is not to find direct relations between members but to find the superordinate system in which they are connected or to define the positional value of members relative to the superordinate system*" (Angyal, 1941, in Emery, 1969: 24).

Summarizing Angyal's view, the key difference between relational thinking and systems thinking is that the first focuses on direct *relations* between two 'members' of the system, while the latter focuses on the members' *positional value* in the system.

As a response to the credo of systems thinking, Angyal remarks that the whole is not only more than the sum of its parts; it is also different from it. Angyal argues that "In aggregates it is significant that the parts are added; in a system it is significant that the parts are arranged" (in Emery, 1969: 26). Also, Angyal argues that for wholes not the inherent qualities of the parts are important, but their position in the 'superordinate' system. Moreover, systems exist independent of their respective elements. Angyal explains this by means of an example of a melody: when you play a certain melody and consequently play it one octave higher, the system (the melody) remains the same while none of its parts (the notes) are the same. Katz & Kahn (1966) put is as follows: "System theory is basically concerned with problems of relationships, of structure, and of interdependence rather than with the constant attributes of objects" (Katz & Kahn, 1966: 18).

As the purpose of this study is to develop a systemic KI model, it is important to keep in mind these differences between systems thinking and relational thinking and between systems and aggregates throughout this thesis.

KI as an Open System

Von Bertalanffy (1950) introduced the concept of an open, living system as opposed to a closed system. While closed systems eventually attain a 'time-independent equilibrium state', Von Bertalanffy observed that in many living systems this does not happen. Rather, these systems attained a 'steady state' where the system "[...] remains constant as a whole and in its phases, though there is a continuous flow of the component materials" (Von Bertalanffy, 1950: 23). Considering that KI concerns the integration of *external* knowledge, we can categorize a KI system as an open system. Open systems are argued to posses each of the following ten characteristics (Katz & Kahn, 1979):

1. *Importation of energy:* Open systems import some form of energy from the external environment. Energy, in this sense, is to be interpreted broadly, as any inflow from the environment that is transformed by the system. Translated to the KI context of this study, this suggests that a KI system imports knowledge from its environment.
2. *Through-put:* Open systems transform the energy available to them. Hence, a KI system will transform the knowledge it imports.
3. *Output:* Open systems export some product into the environment. Thus, a KI system will export something to its environment, for example, applicable knowledge to the new product development process.
4. *Systems as cycles of events:* The pattern of activities of the energy exchange has a cyclic character. The product exported into the environment furnishes the sources of energy for the repetition of the cycle of activities. This is explicitly stressed by Senge (1990). An example in the KI context is when two SMEs cooperate during NPD and mutually exchange knowledge.
5. *Negative entropy:* By importing more energy than it expends, an open system can store energy and thus can acquire negative entropy. For this study, this suggests that part of the knowledge that is imported from the environment is stored in the high-tech SME.

6. *Information input, negative feedback, and the coding process:* The inputs into open systems consist not only of energetic materials, which become transformed or altered in the work that gets done. Inputs also are informative in character. These inputs are used for the self-control of the system. This aspect of open systems is stressed in the field of cybernetics (e.g. Ashby, 1956; Beer, 1972). In the context of this study, this means that next to knowledge for NPD, also knowledge is imported for controlling KI.
7. *Steady state and dynamic homeostasis*: The importation of energy to arrest entropy operates to maintain some constancy in energy exchange. The basic principle is the preservation of the character of the system. This also concerns the preservation of the boundaries of the system. When translated to this study, this means that a KI system is most of the time a system in a steady state with a relatively constant exchange of knowledge with its environment.
8. *Differentiation:* Open systems move in the direction of differentiation and elaboration. Diffuse global patterns are replaced by more specialized functions. For KI, this suggests that, in the course of time, the KI system becomes more and more differentiated into specialized KI subsystems.
9. *Integration and coordination:* As differentiation proceeds, it is countered by processes that bring the system together for unified functioning. Integration is the achievement of unification through shared norms and values; coordination is the addition of various devices for assuring the functional articulation of tasks and roles. Hence, in the course of time, KI systems ask for more coordinative actions.
10. *Equifinality:* Open systems are characterized by the principle of equifinality (Von Bertalanffy, 1950). According to this principle, a system can reach the same final state from differing initial conditions and by a variety of paths. For KI, this suggests that there are more paths (e.g., patterns of activities) towards the same goal.

While it is common knowledge nowadays that social systems – including organizations – are open systems, the notion of 'openness' is not without problems. A system that would be completely open would be indiscernible from its environment; it would not be a system anymore. As a solution to this issue, Maturana & Varela (Maturana & Varela, 1992; Varela, Maturana, & Uribe, 1974) have developed the notion of autopoetic systems, which are systems that are 'at the same time closed and open'. An autopoetic system is closed with respect to its operations and control. It follows a circular logic of self-creation, self-organizing, and self-preserving. It is open with respect to its input and output of materials and energy from and to the environment. It is however the system itself that determines how the environment affects the system. We believe Maturana & Varela's definition of system openness complements rather than contradicts Katz & Kahn's characterization of open systems. While there are differences in their further operationalizations and focus (e.g. the notion of autopoetic systems refers to systems from a perspective within the system, while the notion of an open system refers to systems from the perspective of an outsider), we believe it is sufficient for this study to keep in mind KI as an open system that emerges from the descriptions above.

KI as a Complex System

Besides being open systems, KI systems also are complex systems. What this means becomes clearer when we consider Boulding's (1956) attempt to develop a 'general systems theory'. Boulding distinguishes nine cumulative levels of system complexity:

1. Static system or 'framework', providing the geography and anatomy of the universe. An example is the arrangement of atoms in a molecule;
2. Dynamic system or 'clockwork', providing the predetermined and necessary motions. An example is the solar system;
3. Cybernetic system or 'thermostat', the system will move by itself to any given equilibrium. An example is a temperature regulating thermostat;
4. Open system or 'cell', the system is self maintaining and provides a throughput of some form of material. An example is a river;
5. Genetic-societal system, or 'plant', the system is differentiated into mutually dependent parts. An example is a tree;
6. Information receiving system or 'animal', characterized by increased mobility, teleological behavior, and self-awareness. An example is a mammal;
7. Self-consciousness (reflective) system or 'human', the system is able to reflect its behavior, it is able to interpret symbols. Examples are individual persons;
8. Social system or 'organization', consisting of a set of roles tied together with channels of communication. An example is a firm;
9. Transcendental system, providing absolutes and inescapable unknowables that exhibit systematic structure and relationships.

As Boulding argues, social systems, including organizations, are amongst the most complex systems to be imagined (level 8). Considering that one level of complexity systems possess all the properties of systems at lower levels of complexity, we can characterize complex systems by summarizing the characteristics of the various levels. For the purpose of this study, we are not so much interested in the nine levels themselves. More important is the step-by-step picture from a social system – and thus a KI system – that emerges from them. For example, Bouldings' classification illustrates that a KI system is *not* simply like a thermostat that will move itself towards a pre-defined equilibrium. Rather, a KI system consists of humans who communicate and reflect and have particular roles.

Before we move on to further characterizing KI systems as social systems, we need to address one further characteristic of complex systems. This is the notion of system hierarchy. As Simon has observed, complex systems have a hierarchical structure (Agre, 2003; Simon, 1996). It is important to realize that Simon's use of the word 'hierarchy' is different from its common use. In its common use, the word 'hierarchy' refers to the chain of command in organizations, where higher levels control lower levels. In systems theory, however, hierarchy means something different in that it concerns aggregation rather than control. Put simply, it means that complex systems are 'near-decomposable' into interdependent subsystems. Thus, a hierarchical system consists of subsystems that have an internal cohesion that is greater than the cohesion between subsystems. For example, a university can be decomposed into relatively autonomous schools, which can, in turn, be decomposed into relatively autonomous departments. In this example, there are three levels of aggregation (university, schools, and departments) of which each level represents the complete university. In this use of the word 'hierarchy' there is thus no control involved.

In systems theory, control is conceptualized in another way. To conceptualize control, De Leeuw (2000) distinguishes between a controlling organ (CO) and a target system (TS). It might be useful to remark at this place, that control in systems theory does not imply a strict determination of a TS by a CO, or a close monitoring and regular checks as in accounting. Rather, control means simply any manner of directed influence (De Leeuw & Volberda, 1996). As appears from the word 'directed', a CO gives direction to the TS. In other words, it provides the goals for the TS. Also, it 'influences' the TS towards the achievement of these goals, which means that it tries to change the TS such that it will achieve its goals. When we return to the example of the university, the university, schools, and departments can be seen as TSs that each are controlled by different COs. In case of the university, these COs are relatively external to the TSs: the university is controlled by a rector or governing body, the schools by a dean or management team, and the departments by a department head. In this case, the COs are subsystems, separate from the TSs. It is however not necessary that the TSs are separate subsystems. A concrete system also can be a CO and a TS at the same time. This is the case, for example, in a design team where persons perform and control their design tasks simultaneously. Also, as De Leeuw remarks, the roles of TS and CO can be exchanged. An example is when we consider the university department as a CO controlling its department head.

The concepts of system hierarchy and control are depicted in Figure 1.1, which represents two levels of a hierarchical KI system. More levels of aggregation could be added (for example, a KI 'supersystem'), but to keep Figure 1.1 readable, we limited it to two levels. In the figure we see that TS 1 consists of four subsystems (1a - 1d) having their own COs (1a – 1d). On its turn, TS 1 is controlled by CO 1. Throughout this thesis we will see how explicitly distinguishing hierarchy from control is helpful in analyzing KI.

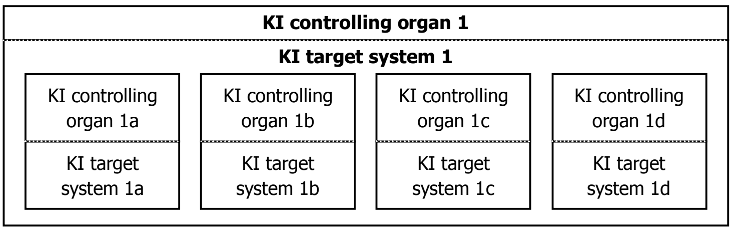


Figure 1.1 KI as a hierarchical system and its controlling organs

KI as a Social System

While the notion of an open and complex system applies to fields including biology and psychology, we can further fit systems thinking to the purpose of this study by categorizing a KI system as a social system. Although there have been, and still are, severe debates about the characteristics of social systems amongst influential sociologists (e.g. Parsons, Luhmann, Habermas, and Merton) and their followers and critics (e.g. Alexander, Wearne, Savage, and Künzler), there seem to be some common characteristics to all social systems. Katz & Kahn formulate them as follows: "All social systems, including organizations, consist of the patterned activities of a number of individuals. Moreover, these patterned activities are complementary or interdependent with respect to some common output or outcome; they are repeated, relatively enduring, and bounded in space and time." (1966: 17). In this summary of a social system we find the following characteristics of social systems:

1. Social systems consist of the patterned activities of a number of individuals. Simply put, an activity can be anything that somebody does with a purpose or from his own initiative (as opposed to behavior that is purely reactive like in a stimulus-response relationship, (Coleman, 1986)). Other terms that are used to refer to activities are 'action', 'act', 'unit act', and 'event'. The importance of activities rather than things in a social system theory makes some scholars even refer to it as a theory of action (Parsons, 1977). When we accept that a KI system is a social system, this suggests that a KI system consists of KI activities performed by a number of individuals.
2. The fact that social systems consist of patterns of activities rather than things makes that, unlike biological systems, social systems have no anatomical (physical) structure. Rather, the structure consists in the patterns of activities and in their interactions themselves (Katz & Kahn, 1979:7, Luhmann, 1995). This implies that the structure of a KI system is formed by patterns of KI activities. A KI subsystem, then, exists of particular patterns (or at least one pattern) of KI activities.
3. Social systems (and their subsystems and individual actors) are directed towards certain goals. This means that the patterns of activities are performed to achieve one or more goals. However, "The fallacy here is one of equating the purposes of goals of organizations with the purposes and goals of individual members" (Katz & Kahn, 1966: 15). For a KI system this means that the system, its subsystems and its individual actors have goals that are at least to such extent congruent that they lead to some common output.

Sommerhoff (in Emery, 1969) discusses two additional characteristics:

4. Social systems have multiple levels. The notion of system applies, for example, to the level of small groups, organizations, and society. This implies that social systems are recursive. For example, at any level, we can distinguish target systems and controlling organs. We have explained this above when we discussed the hierarchical nature of KI as a complex system.
5. Finally, in every social system there seems to be a process of adaptive change, in which the system adapts itself to changing internal or external influences. This process is also called 'learning' (e.g. Sommerhoff in Emery, 1969). Since in a social system there is no physical structure, social systems can change faster and more than, for example, biological systems. The basic driver behind change is supposedly the maintenance of the integrity and continuity of the system itself (Selznick, 1948). For KI, this means that a KI system constantly has to consider change in order to deal with internal and external pressures.

While human actors play an important role in organizations, they are not the only players. Organizations also consists of technologies (Emery, 1993). Simply put, technologies, in the meaning it is used here, are the non-human objects of a system. They are artifacts like machines and materials (Ackoff, in Emery, 1969: 333; Emery, 1993). A field that particularly addresses the interplay between these two types of system elements is that of socio-technical systems theory. Originating from the Tavistock Institute and concentrating on work redesign, Trist and Emery have developed the notion of a socio-technical system. Later on, the notion of a socio-technical system has been further elaborated upon by scholars including Senge (learning organization, Senge, 1990), Latour (actor-network-theory, Latour, 2005), and Giddens (structuration theory, Giddens, 1984). The core idea of socio-technical systems is that different social systems can effectively operate the same technology (Emery & Trist, 1960). Trist & Emery argue, "The technological component has been found to play a key mediating role and hence it follows that the open system concept must be referred to the socio-technical system, not simply to the social system of an enterprise" (Emery & Trist, 1960: 86). From this we take that KI activities are performed in interplay between human actors and technology and that a KI system consists of three types of elements: human actors, technology, and activities. Throughout this thesis we will see what this means for a systemic KI model.

KI as an Aspectsystem

So far, we have built up the image of a KI system as a social system. However, it is obvious that a KI system does not concern all aspects of a social system; otherwise there would be no need to call it a *KI* system. Hence, a KI system concerns only one *aspect* of a social system: the KI aspect. While this seems trivial, this has important consequences for how we treat it as a system. To understand the idea of an aspectsystem, it is useful to distinguish it from a subsystem and a phasesystem, which are three distinct ways of distinguishing *partsystems* of a system (De Leeuw, 2000):

- A *subsystem* is limited to part of the collection of system elements, but considers all types of relations between these elements. An example is concentrating on the sales department of an organization.
- A *phasesystem* considers all elements and relationships of a system but is limited to a particular timeframe. An example is concentrating on the organization in the short term.
- An *aspectsystem* considers all elements of the system, but is limited to particular type(s) of relationships. An example is concentrating on power relationships within the organization.

Hence, as aspectsystem, a KI system considers all elements of a concrete system, but is limited to the knowledge aspect of this system. An important consequence of looking at KI in this way is that knowledge also is seen as an aspect of a concrete system rather than as a separate object within a concrete system. In order to avoid ambiguity in this study, we specify this view on KI systems somewhat more at this place.

Above, we have identified three elements of a KI system: activities, human actors, and technology. The core of a KI system is formed by *KI activities*. KI activities are those activities of which knowledge is the object. Hence, these activities change some property of knowledge, like its location or its level of codification. These activities are performed by *actors* having roles as, for example, knowledge seekers, knowledge sharers, and knowledge users. Dependent on the level of analysis, these can be individual actors or collectives (in both cases we refer only to human actors). In order to perform activities, actors use *technologies* like computers and pencils. When a KI system is considered as such, knowledge is an object within a particular aspectsystem (the KI system). On its turn, we consider knowledge to be an aspect of a concrete system. This concrete system also consists of actors (e.g. in roles as engineers and marketeers), technology (e.g. machines and working place), and activities (e.g. drilling a hole and welding two pieces of metal). Since we are only interested in the knowledge aspect of these actors, technology, and activities, we consider them as knowledge carriers within the KI system. This is depicted in Figure 1.2, which should be read from top to bottom.

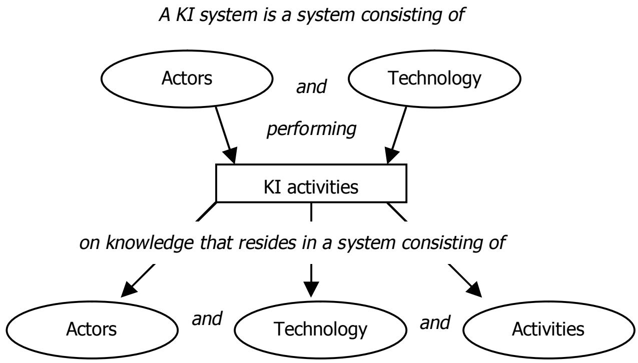


Figure 1.2 A KI system as an aspect system

On Interconnections

Above, we have discussed the types of elements which comprise a KI system. What however has remained somewhat unclear is how they comprise a system. This concerns the question as to how these elements are *connected*. When we invoke some of the discussions from above, it is clear that the various scholars do not deal with the connectedness of system elements in the same way. For example, while Dubin (1978) speaks of interaction, Ackoff (in Emery, 1969) speaks of interdependence, and De Leeuw speaks of relations (De Leeuw, 2000). Also, different types of connectedness are sometimes used interchangeably. An example is Katz & Kahn (1966) who use the terms interdependence, relationships, exchange, complementarity, and interactions without explicating their similarities and differences. Finally, it is clear from ongoing debates in sociology that there is no agreement what should be the central concept of interconnections in social systems: some say communication, others say exchange (Habermas, 1987; Johnson, 1973; Künzler, 1989; Luhmann, 1977; Parsons, 1961).

In this study, we have no intention to conclude any of the ongoing discussions on interconnections between system elements. Neither will we fully take account of all the possible types of connectedness that exist between elements of a KI system. Rather, based on our short discussion on autopoetic systems, we will distinct two types of interconnections that appear to be relevant to this study: connections between KI systems, and connections within KI systems. In the first case we see a KI system as a black box where we are only interested in its inputs and outputs. As we will explain further in Chapter 4, in this case the central concept of connections is an interchange. Put simply, this means that system A receives something from system B and system B receives something in return. In the case of connections within a KI system, we open up the black box in order to see how the system is realizing its output and how it is maintaining itself. As mentioned earlier, this concerns the patterns of KI activities that lead to the output of a KI system. In this case, the elements of a KI system are connected by their contribution to a common output.

We have argued before that a KI system is recursive. This implies that connections between KI systems at one level are connections within a KI system at a higher hierarchical level. Hence, it might seem strange that we have distinguished two types of interconnections. We have done this, however, since we believe that when we focus on a particular hierarchical level, the two types of interconnections are the most relevant ones to consider at that level.

1.2.2 On a Systemic KI Model

In the previous subsection, we have discussed KI systems to explain the reader what it means to regard KI as a system rather than a collection of standalone activities. The objective of this study, however, is to develop a systemic *model* of KI. This subsection will classify and characterize such model and specify evaluation criteria for it. After this, Section 1.3 will return to the problem addressed in this study by elaborating how such model is to contribute to research and practice.

Type of Model

Generally speaking, a model is “a system resembling (the relevant aspects of) another system (or class of systems) that is to be studied, controlled, or designed” (De Leeuw, 1999: 201). Bertels & Nauta (1969) distinguish three types of all possible models:

1. Empirical models: consisting of concrete entities (objects). An example is a scale model of a building.
2. Conceptual models: consisting of conceptual entities (concepts). An example is conceiving the human brain as a computer.
3. Formal models: consisting of formal entities (signs). An example is a formula for gravitation.

Conceptual models are further specified into a) theoretical models, modeling an empirical system; and b) realization models, modeling a formal system. The systemic KI model that is targeted at in this study is a conceptual model, or more specifically, a theoretical model. Parsons explains this as follows: “An empirical system, then, is a body of presumptively interdependent phenomena to which a given abstract analytical scheme is presumptively relevant” (Parsons, 1961: 32). A systemic KI model is a conceptual model of KI in practice.

A further characterization of the systemic model to be developed in this study is by its function (or purpose). In this study, we will develop a ‘thinking model’ (Bertels & Nauta, 1969) or ‘lens’ ('kijkmodellen', De Leeuw, 1999). They are used as lens to look at a particular phenomenon. These models direct the selection and interpretation of relevant facts and often they provide a comprehensible overview of phenomena (Bertels & Nauta, 1969: 119). Hence, the systemic KI model to be developed in this study is a conceptual thinking model that is based on the analogy of a system and that is used to select, interpret, and organize KI phenomena.

In order to further specify a systemic KI model it also is helpful to compare the notion of a (systemic) model to the notion of a theory. While some philosophers use the terms interchangeably (e.g. Dubin, 1978), we believe that for the particular type of model of this study the difference is relevant. According to Bunge “[...] scientific theories deal with [...]

models that are supposed to represent, in a more or less symbolic way and to some approximation, certain aspects of real systems [...]" (Bunge, 1998a: 439). Or put in other words "A theory as a whole *refers* to a system or, rather, to a class of systems, and the model involved in the theory *represents* the system" (ibid, original italics). Hence, a systemic KI model is a model that represents KI in practice and that can be used in theories of KI. In this view, a systemic KI model it is not a theory itself.

Characteristics

A systemic model as typified above is a system of interrelated concepts that refers to some empirical phenomenon (Bunge, 1998b). While this applies to all conceptual models, it is the type of concepts and interrelationships that make a model a systemic model. These concepts have been mentioned in the elaborations on KI as a system in Subsection 1.2.1. Below, we will summarize and organize them. As mentioned in Subsection 1.2.1, the central concept of a KI system is the concept of a KI activity. However, KI activities do not occur in isolation. Hence, we need additional concepts to model a system of activities. It is common amongst authors in systems theory to distinguish between the structural characteristics of a system, its behavioral characteristics, and its control characteristics. While the structural characteristics indicate what a KI system *is*, the behavioral characteristics indicate what a KI system *does*, and the control characteristics indicate what a KI system *should* be and do. Based on the elaborations on the concept of a KI system in Subsection 1.2.1 we can now provide each of these three types of characteristics of a systemic KI model. With respect to the structure of a KI system, a systemic KI model should recognize

a. that a KI system consists of actors and technology that together perform KI activities on knowledge; in the remaining part of this thesis we refer to these as the **elements** of a KI system.
b. that a KI system has boundaries. Since it concerns an open system, the model also should recognize that these boundaries are permeable. We will refer to this as the **boundaries** of a KI system.
c. that a KI system is part of a supersystem in which it has a function and that the system is composed of functionally distinct partsystems (with at the lowest level individuals) having different functions in the system. We refer to this as the **internal structure** of a KI system.

With respect to the behavioral characteristics of a KI system, a systemic KI model should recognize

d. that within a KI system, KI activities are differentiated and patterned into several functions. Part of the activities of the system is used to transform inputs into outputs and part of the activities of the system is used for the maintenance of the system, which includes the preservation of the system boundaries. We refer to this as the **patterned activities**.
e. that a KI system interacts with other systems, usually in a cyclical way. These can be other KI systems, other types of systems (e.g. the manufacturing system within a firm). This implies the recognition that parts of the system are interdependent; they cannot do without each other. This is referred to as **interchange**.

Finally, concerning the control characteristics of a KI system, a systemic KI model should recognize

f. that a KI system is goal-directed; it has a purpose in itself (in the supersystem); moreover, it should also recognize that KI subsystems and individual actors have goals themselves, which might not be congruent with the goal of the system. We refer to this as **goal-directedness**.
g. that a KI system evolves. Since a KI system is open it interacts with its environment and adapts to changes imposed by the environment and by internal tensions. The system as a whole is moving towards a 'steady state' This includes the recognition that a KI system exhibits a form of self regulation. We refer to this as **evolution.**

Throughout this thesis, we will use these seven characteristics to describe a systemic KI model. It is good to realize here that they are characteristics and not separate parts of KI. For example, the structure of a KI system instantiates in patterns of KI activities. KI should be seen as a dynamic whole in which actors try to achieve their goals by performing KI activities and using technologies. The seven characteristics systematically highlight different aspects of this whole.

As argued before, systemic models can be developed at different hierarchical levels, including the level of groups, organizations (as a system level, not necessarily related to legally distinct organizations), and societies. As mentioned in Section 1.1, the empirical context on which this study focuses is KI in high-tech SMEs. Hence, the focus is clearly not on KI at the level of societies. Consequently, we will leave levels higher than the level of organizations out of consideration in this study.

Evaluation Criteria

With these seven characteristics we have specified what a KI model should cover in order to be a systemic model. However, we do not target just any systemic KI model. Rather, we also want the KI model to be a high-quality model. This implies that it should fulfill certain criteria. While there exists a repertoire of research criteria (e.g. falsifiability, validity, reliability, and generalizability), there is substantial doubt whether these criteria are sufficient, or even appropriate for evaluating a systemic model or any other type of conceptual model (De Leeuw, 1999; Jarvie, 1973). For example, instruments like SWOT analysis, Porter's five force model, and the balanced scorecard of Kaplan & Norton are conceptual models that are appreciated in practice but the criterion of falsifiability is certainly problematic (cf. De Leeuw, 1999). But should we therefore abandon these models? We believe not. Rather, we should find more appropriate criteria to evaluate such models.

De Leeuw (1999) provides a set of such criteria, which we will adopt in this study. According to De Leeuw (1999), the quality of conceptual models is mainly to be judged by their *usefulness* for studying, controlling, or designing other systems. Usefulness is further decomposed into soundness and relevance. Soundness refers to a carefully defined domain of validity and rigorous foundations of the maintainability of the specific claim that is attached to the model. It is decomposed into correctness, consistency, and precision. Relevance refers to the reporting of where and how the model is fulfilling the knowledge need. It is further decomposed into manageability, fit with the problem, and timeliness. Since the exact operationalization of these criteria depends on the evaluation method, we postpone a further discussion to Chapter 5, in which the systemic KI model will be evaluated.

Similar types of criteria can be found in the field of design science. While the focus of that field is mostly on the design of artifacts and not on conceptual models, the types of criteria that are used are similar. For example, Hevner, March, & Park (2004) mention the following criteria: utility, quality, efficacy, functionality, completeness, consistency, accuracy, performance, usability, fit with the organization, 'and other relevant quality attributes'. However, since De Leeuw's set of criteria particularly addresses conceptual models and since it is a structured set of criteria, we prefer it above Hevner, March, & Park's illustrative list of criteria.

1.3 Targeted Contribution

The preceding two sections have characterized the problem addressed in this study and the targeted outcome of this study – a systemic KI model. This section discusses how a systemic KI model is to contribute to the solution of the practical KI problem introduced in Section 1.1 and what scientific contribution a systemic KI model can make. In general, the contribution of a systemic model is that it is an "[...] analytical tool. It ensures that nothing of vital importance is inadvertently overlooked, and ties in loose ends, giving determinacy to problems and situations. It minimizes the danger, so serious to common-sense thinking, of filling gaps by resort to uncriticized residual categories" (Parsons, as quoted by Savage, 1981: 146). In Subsections 1.3.1 and 1.3.2, respectively, we will discuss how a systemic KI model is to make this contribution to KI practice and KI research.

1.3.1 Contribution to Practice

We can summarize the practical KI problem as discussed in Section 1.1 by stating that KI is a complex process of interconnected activities of which managers do not have a sufficient overview to manage and control it effectively. As the empirical field in which this study investigates KI is the field of new product development in high-tech SMEs, the problem owners are managers of high-tech SMEs. Now, after our discussions on KI as a system, we can further specify the problem owners. In Subsection 1.2.1 we have argued that a KI system is controlled by a controlling organ (CO). In this study, it is this CO that is considered to be the problem owner. While it seems likely that SMEs' managers will have a role in this CO, this is not necessarily the case. The CO of a KI system also can consist of, for example, a project manager, an R&D manager, or a team of employees involved in NPD. When we return to the problem that was described in Section 1.1, it is thus the CO that does not have a sufficient overview of the KI system to control it as effective as it could be done.

The role of a systemic KI model in controlling KI can be specified by considering control as a problem solving process. In the literature, both control and problem solving are associated with attempts to achieve a desired end (Smith, 1989; De Leeuw, 2000). From this perspective, control and problem solving are similar. We have chosen the problem solving process to explain the role of a systemic KI model, because we believe it describes better the different ways the model can be used than the control process does. Hence, the systemic KI model developed in this study should be an instrument supporting KI problem solving.

Based on existing conceptualizations of problems, we assume that a KI problem is an undesirable situation in a KI system that is significant to and may be solvable by the CO of that KI system, although probably with difficulty (Agre, 1982; Smith, 1989). From the literature on problem solving (e.g. Smith, 1989), we take that KI problem solving consists of three interdependent tasks: problem identification, problem analysis, and problem solution. We believe that the systemic KI model targeted in this study can facilitate each of these three tasks. This is depicted in Table 1.1 and described below.

Problem identification leads to the perception of a problem (Smith, 1989). In the course of time, people develop certain patterns of working. When major problems arise in these patterns, these problems will be perceived. However, when problems arise gradually, the patterns will continue to exist and the problems will remain unnoticed (Senge, 1990). There is no reason to believe that this principle does not apply to gradually emerging KI problems. We assume that these will remain unnoticed for a long time, until it is perhaps too late to solve them. The first potential contribution of the systemic KI model concerns the perception of these gradually emerging KI problems. A systemic KI model provides practitioners with a way of looking at their organization. Because the model is supposed to cover the KI system in its entirety, the model facilitates practitioners to look at more things than they would look at without the model. As such, the model is used as a descriptive instrument: it describes the static and dynamic characteristics of KI in practice. When the model is used as a descriptive instrument, this hypothetically leads to earlier KI problem detection or the detection of more KI problems.

Problem analysis leads to a definition, a conceptualization, and finally a diagnosis of a problem (Smith, 1989). While problem identification leads to the insight that there is a problem, problem analysis leads to an explanation of what the problem is and why it is there. When used for this second task of problem solving, the systemic KI is used as an explanatory instrument. For example, the model can help practitioners to find out whether the problem is related to the structural, behavioral, or control characteristics of the KI system, or whether it is caused by a defective element or a missing interchange. It might be useful to remark here that the model itself does not provide the explanation (or cause) of the problem (otherwise it would not have been a thinking model but an explanatory model). Rather, it facilitates practitioners in finding explanations by showing interconnections between parts of the model.

While a good diagnosis of a KI problem already provides part of its solution, additional creativity is needed in order to solve the problem (Smith, 1989). When used for the solving of KI problems, the systemic KI model is used as a prescriptive instrument. Although the systemic model is, as many other models, not neutral, the model in itself is however not intended to be a prescriptive model. It is not a normative design of a KI system. Rather, the systemic model forms a means to generate alternative solutions (or at least one), a means to facilitate the choice of a solution, and a means to design and implement this solution. Hence, it is good to realize here that it is not always necessary to have a KI problem explained before it can be solved and that there can be various solutions for one KI problem (equifinality). An example in practice is a workaround, where although the cause of a problem is not found, a solution has been created.

Table 1.1 Three types of practical contributions of a systemic KI model

Task	Outcome	Contribution of a systemic KI model
KI problem identification	Perceived KI problem	Instrument for description
KI problem analysis	Diagnosis of the KI problem	Instrument for explanation
KI problem solution	Solution of the KI problem	Instrument for prescription

While these three types of contributions to KI problem solving can be realized by any conceptual thinking model, a systemic model is particularly suitable to make these contributions. More than other types of models, a systemic model will show the complexity and the coherence of KI in practice. This should lead to practitioners that use the model being able to identify, analyze, and solve more KI problems than they currently are able to or than they are able to with a partial (as opposed to systemic) KI model.

We assume that KI problem solving often involves more than one individual. When this is the case, an additional contribution of the systemic model is that it can facilitate the discussion amongst the involved individuals. The model explicates what characteristics of KI should be discussed and how these characteristics relate. This supposedly improves the effectiveness and efficiency of communication between the individuals involved in KI problem solving.

1.3.2 Contribution to Research

Research on KI is at the end of its fourth decade now (Kwasitsu, 2003). In the past four decades there has appeared an abundance of publications on KI. While in the last decade some of these publications explicitly use the term KI (De Boer, Van den Bosch, & Volberda, 1999; Grant, 1996; Jetter et al., 2005; Murray, 1995), by far most publications have used other terms to refer to the processes of identifying, acquiring, and utilizing external knowledge. These terms include environmental scanning (Aguilar, 1967; Choo, 2002), information seeking (Case, 2002; Taylor, 1968), and information processing (Galbraith, 1974; Levin, Huneke, & Jasper, 2000). Although an exact estimate of the number of publications in these areas is unimportant here, we estimate that there are at least thousands, but more likely, tens of thousands of scientific publications on KI.

When we consider the type of research that has been done, we can observe that there is a large variety in research. For example, some publications provide models of knowledge identification (e.g. Aguilar, 1967; Daft & Weick, 1984; e.g. Ellis & Haugan, 1997), others of knowledge acquisition or transfer (e.g. Argote, 1999; e.g. Inkpen & Dinur, 1998; Mowery, Oxley, & Silverman, 1996; Szulanski, 2000), and others of knowledge utilization (e.g. Majchrzak, Cooper, & Neece, 2004; Markus, 2001; Stein, 1995). There are also publications that regard KI as a black box and that rather elaborate on explanatory models of KI success (e.g. De Boer, Van den Bosch, & Volberda, 1999; Gray & Meister, 2004; e.g. Hamel, 1991; Hansen, 2002; Lane & Lubatkin, 1998; Mowery, Oxley, & Silverman, 1996; Szulanski, 1996; Thomas, Clark, & Gioia, 1993; Zander & Kogut, 1995). Moreover, we also find numerous articles that aim at the improvement of certain KI activities. These include the design of information systems (Alavi & Tiwana, 2002; Barrick & Spilker, 2003), methods and techniques (Binney, 2001; Faran, Hauptman, & Raban, 2005), organizational forms (Bell, Giordano, & Putz, 2002; Boari & Lipparini, 1999; Brown & Duguid, 2001), managerial interventions and incentives (Okhuysen & Eisenhardt, 2002; Osterloh & Frey, 2000) and organizational processes (Lyons, 2000; Ravasi & Verona, 2001).

Despite the wealth of high-quality publications on KI, there is still an explicitly expressed need for a better understanding of KI (Grant, 1996; Ranft & Lord, 2002). We believe that an important cause of this seeming contradiction is a lack of cumulativity in KI research. Rather than being cumulative, KI research is fragmented and scattered along various disciplines. While Chapter 2 of this study will show this in detail, we will give one example here. This concerns the fact that various scholars sometimes use different terms to refer to the same activity (synonyms) or use the same term for different activities (homonyms). An example of the first concerns the activity of transforming tacit knowledge into explicit knowledge. While Nonaka (1994) calls this 'externalization', Hedlund (1994) calls it 'articulation'. An example of homonymity concerns the use of the term 'combination'. Kogut & Zander (1992) use the term to refer to the combination of existing and new knowledge; Nonaka (1994) uses it to refer to the creation of explicit knowledge from other explicit knowledge; and Wiig, De Hoog & Van der Spek (1997) use it to refer to the synergy and reuse of existing knowledge. Moreover, some authors are rather creative in their terminology. For example, Hedlund (1994) uses the term 'appropriation' when he refers to the situation "[...] when the organization teaches new employees about its products [...] or indoctrinates them into the corporate culture" (Hedlund, 1994: 77). Since this confusing use of terminology is far from exceptional in KI literature, we find it not surprising that there is a lack of cumulativity.

This lack of cumulativity also has been observed by others in related fields of research. For example, in his review of the literature on organizational learning, Huber already remarked in 1991 that "[...] there is a lack of cumulative work and a lack of synthesis of work from different research groups" (Huber, 1991: 107). Most synthesis has probably been brought by the various review articles that appear within certain research disciplines (e.g. Alavi & Leidner, 2001; Argote, McEvily, & Reagans, 2003; Case, 2002; Lord & Maher, 1990; Zahra & George, 2002). These provide an overview of the relevant concepts within a discipline. Practice is however not organized by research disciplines, or as Popper puts it: "We are not students of some subject matter but students of problems. Any problem may cut right across the borders of any subject matter or discipline" (Popper, 1963: 67).

The lack of cumulativity in research has been one of the impulses for developing systems theory. For example, as a response to 'a crisis of science' and an imminent 'intellectual civil war between disciplines', Boulding (1956) has suggested a general systems theory that should serve as a skeleton for all scientific disciplines (see Subsection 1.2.1). While Boulding's attempt has been unsuccessful until now, we are convinced that systemic models on a less general level can facilitate accumulation of research. A systemic KI model could serve as an ontology of what KI is and thus as a basis for developing cumulative KI theories. When accepted by a substantial number of researchers, such ontology could reduce confusion and fragmentation of research. Of course, it is unrealistic – and undesirable – to think that all KI researchers will adopt a similar ontology of KI. When universally accepted, an ontology can become an unquestioned doctrine that reduces the necessary variety of research (cf. Feyerabend, 1993). However, given the current large fragmentation of KI research, there currently seems no reason to fear that too much agreement will emerge now or in the near future. On the contrary, we believe that currently there is a need for reducing variety and for more agreement on KI ontology. A systemic KI model can contribute to this by systematically characterizing the elements and interrelationships which comprise KI. In terms of Davis' (1971) classification of twelve types of theoretical contributions (Generalization, Organization, Causation, Opposition, co-Variance, co-Existence, co-Relation, Function, Abstraction, Composition, Evaluation, and Stabilization), the contributions of a systemic KI model concern:

1. 'Organization' which is that "when people assume that a phenomenon is disorganized or unstructured and then discover that it is really organized" (Weick, 1969: 53): the systemic model resulting from this study will provide a structure for the currently unstructured collection of KI concepts.
2. 'Composition' which is that "what seems to be heterogeneous phenomena are actually composed of a single element": while the current literature on KI seems to assume that KI activities are separate entities, the systemic model of this study will show how they are a decomposition of a KI system.

While we make extensive use of principles from system theory in this study, our intended contribution is mainly to the KI literature and less to systems theory literature.

1.4 Research Approach

As our objective is to develop a systemic KI model rather than to test an existing model, this study can be characterized as a model development project. On the one hand, such project could be categorized as a design science project, which produces "a viable artifact in the form of a construct, a model, a method, or an instantiation" (Hevner, March, & Park, 2004: 83). However, when we scrutinize some literature on design science (Markus, Majchrzak, & Gasser, 2002; Nunamaker Jr., Chen, & Purdin, 1990-91; Van Aken, 2004; Walls, Widmeyer, & El Sawy, 1992) there is an almost exclusive focus on the design of 'instantiations'. This literature focuses on the construction, implementation, evaluation, and improvement of instantiations in practice. However, since there is little guidance as to how a conceptual model is to be developed, this literature does not help us much in choosing our research approach.

On the other hand, a model development project also could be categorized as a theory development project. Although we adopt Bunge's view of the difference between models and theories (see Subsection 1.2.2), the two terms are often used interchangeably in publications on theory development (e.g. Dubin, 1978: 10). In these publications, the term 'theory' is used in a broad sense which includes conceptual models. This implies that we can ground on the more developed body of literature on theory development. When we refer to this literature in this section, we will use the broader term 'theory' because what is said does not only apply to models and because it is the term used by the authors we refer to. Before we can move on to discussing the research questions and the research strategy of this study (Subsection 1.4.2), it is useful to spend some words on the question as to how we see the relationship between theory, empirics, and the researcher (Subsection 1.4.1).

1.4.1 Theory, Empirics, and the Researcher in Model Development

Regarding the relation between theory and empirics, there is an energy consuming ongoing debate between the so-called 'positivist' and 'interpretivist' research paradigms in the organization and information sciences (Jones, 2000; Lee, 1991; Mingers, 2001). While it is tempting to mingle in this debate, we confine ourselves to expressing the belief that although the paradigms might be analytically distinct and incommensurable, every study is likely to contain elements of both. The same holds for the distinction between inductive and deductive research. We agree with Dubin who argues that "[...] the words *inductive* and *deductive* describe only a direction of movement. Focusing on induction and deduction separately leaves out of the picture what is most important: the nature of the model to which both deduction and induction refer, and the linkages between the model and the empirical world to which it applies" (Dubin, 1978: 18, original italics).

Our assumptions can be summarized by the statement that there is no direct connection between theory and empirics (Lakatos, 1970). As a result, "we cannot prove theories and we cannot disprove them either" with empirics (Lakatos, 1970: 100). What remains is that we can improve them. Improving theories implies that research starts with a theory and improves it based on other theories, insights of the researcher, and/or on empirical data. While scholars as Popper (1959), Kuhn (1996), Glaser & Strauss (1967), Dubin (1978), and Weick (1989) differ in their suggested approaches for theory improvement, they all agree that a theory can only be replaced by a better theory. Popper's approach presupposes the existence of a testable theory. For this study, following Popper's approach would mean that there is an existing falsifiable systemic KI model that we can try to refute. As we will see in Chapter 2, this is not the case. This suggests that we cannot start with an existing systemic KI model and try to refute it. This leaves us with the alternative approach propagated by Dubin (1978), Weick (1989), and Glaser & Strauss (1967). These scholars plead for an approach that, next to the use of existing theory and literature, includes more creativity and imagination than Popper probably would allow. Since, as stated above, theory cannot be induced from practice or deduced from theory alone, it is not surprising that, in theory development, the individual researcher plays a central role (Länsisalmi, Peiró, & Kivimäki, 2004: 249). As any activity of creation (or design), theory development requires imagination (Weick, 2002), creativity (Laurel, 2003), insights (Glaser & Strauss, 1967) or theoretical sensitivity (Glaser, 1978) from the researcher.

While these considerations do not provide us with specific guidelines for theory development, we take from it that an approach for theory development should make use of existing theory, empirical data, and the researcher. This is central in Weick's approach to theory development, which we adopt in this study. According to Weick, theory development is very much similar to the concept of sensemaking. Sensemaking is the process in which cues are collected and put in a framework where they have a connection – in which they 'make sense' (Weick, 1989; Weick, 1995). As an example of the failure of sensemaking (or the failure of imagination) Weick (2005) describes the terrorist attacks on 11 September 2001. While the intelligence agencies found e.g. that people were taking flying lessons but had no interest in take off and landing whatsoever (i.e. the cues) they did not imagine situations in which this would make sense, like a terrorist attack (i.e. the framework in which the cues make a connection). Rather they were blinded by their view that one only takes flying lessons to become a pilot. While the results of our study are highly unlikely to prevent terrorist attacks, it is this connection between cues that we try to find. We will look for cues in existing theories and in empirical research from which we will try to develop a systemic KI model in which they make sense (are connected).

1.4.2 Research Questions and Strategy

As mentioned in Section 1.1, the proposition of this thesis is that a systemic KI model will provide the overview of KI that is currently lacking and hindering KI problem solving. As it does not exist yet, the objective of this study is to develop such model. After the discussions on how such a model contributes to KI problem solving in Section 1.3, we can now formulate our main research question as follows: '*What systemic KI model can support the identification, explanation, and solving of KI problems that without such model would remain unidentified, explained, or solved?*' In order to answer this question we will develop a systemic KI model and evaluate it, guided by three research questions that are discussed below.

Developing a model or a theory requires the researcher to be an "[...] inveterate collector of facts[4], with an especially well-developed sensitivity to their interrelationships" (Dubin, 1978: 228). This suggests that theory development requires a rich set of research materials (Glaser & Strauss, 1967) and imagination of the researcher (Weick, 2002). Following this guideline, this study will build on three different types of material: literature, empirical material, and the researcher. We will not use this material all at the same time, and for the same goal. Rather, there are three different goals for which the material is used, that correspond to three phases of this study: analysis, design, and improvement. The types of materials and their contribution to the three research phases are depicted in Figure 1.3, which represents the research framework of this study. Figure 1.3 already mentions the corresponding research questions and chapters, which are explained below.

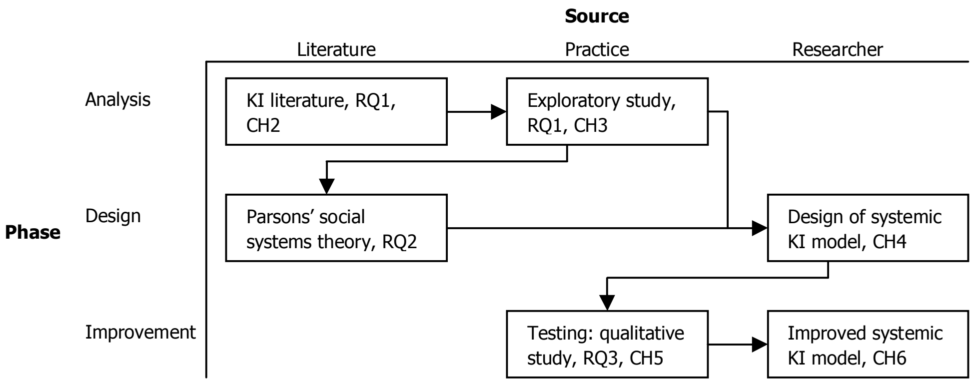


Figure 1.3 Research Framework

[4] A 'fact', according to Dubin, is always shaped by the theory that is used to collect it.

The first phase of this study is an analysis of material that is needed in order to design a systemic KI model. As mentioned above, there is a wealth of literature on KI available in a variety of disciplines. Since this literature can provide a rich picking for developing the systemic KI model, we will start our model development journey in the current KI literature. As Figure 1.3 shows, additional empirical material will be analyzed as well. The literature review and empirical data collection will be guided by the following research question:

1. What theoretical and empirical material for developing a systemic KI model can be derived from the current understanding of the KI process?
    a. To what extent does the current KI literature provide sufficient theoretical and empirical material for developing a systemic KI model?
    b. To what extent does an additional empirical study on KI provide the empirical material that is missing in the current literature?

In order to answer RQ1a we will conduct a cross-disciplinary literature review, using the seven characteristics of a systemic KI model as a lens (see Subsection 1.2.2). This lens is used because it provides us with a straightforward and structured way to analyze the existing literature on KI. Our answer to RQ1a will provide an overview of what scholars in a range of disciplines have published on the seven characteristics of a systemic KI model. We consider this material to be sufficient when 1) there is theoretical and empirical material on each of the seven characteristics; and 2) this material refers to an underlying systemic framework that can be used to develop a systemic KI model. This second requirement is added because such framework is needed for the selection of material from the literature and for constructing a systemic KI model from it. Without such framework, it will be very difficult to distill one systemic model from the vast amount of KI literature. If the current literature does not provide information on all seven characteristics and/or does not provide an underlying framework, then there are gaps in the current literature that need to be bridged before we can develop the systemic KI model. We will bridge these gaps by an empirical study that is guided by RQ1b. Since the research strategy for RQ1b depends on the answer to RQ1a, we have to mention at this place the gaps that will be uncovered in Chapter 2. These are 1) a lack of evidence of empirical patterns of KI activities; and 2) a lack of a clear underlying framework.

In RQ1b we try to bridge these two gaps with an empirical study in the context of new product development in high-tech SMEs. This empirical study consists of two parts: semi-structured exploratory interviews and a large-scale questionnaire. In the exploratory interviews, SMEs will be asked about the way KI is conducted in their firm and the problems that occur during KI. The purpose of these interviews is not data collection per se, but orientation in the field in order to create a good questionnaire, which comprises the second part of the empirical study. The main purpose of the questionnaire is finding empirical patterns of KI activities and finding an underlying framework (in other words, bridging the gaps identified in RQ1a). A quantitative study is particularly well suited for that task since it is able to uncover statistical patterns across a relatively large group of respondents. Both the interviews and the questionnaire will be conducted as part of the European Project 'Knowledge Integration and Network eXpertise' (KINX). While this has several disadvantages (e.g. multiple interests, very broad range of topics, fixed time schedule and sample size) this provides an opportunity to gather a rich set of quantitative data in four countries: Germany, Israel, Netherlands, and Spain. Especially for this early stage of the research this is important because it generates variation in the type of respondents (Weick, 1989). As we did for RQ1a, we also have to provide the answer to RQ1b already at this place since the subsequent research questions depend on it. As Chapter 3 of this study will show, the empirical study provides the additionally required material that is lacking in the current KI literature: empirical patterns of KI activities and a strong indication for Parsons' social systems theory as an underlying systemic framework.

The second phase concerns the actual design of the systemic model. As depicted in Figure 1.3, we will use the results of the analysis phase and complement it with literature on Parsons' social systems theory. Also, being a design phase, this phase requires creativity and imagination of the researcher as an additional input. The research question that guides this phase of the research is:

2. What systemic KI model can be derived from the framing of the gathered material into Parsons' social system theory?
    a. To what extent is Parsons' social system theory applicable to the KI context?
    b. What systemic KI model can be derived from the framing of the gathered material into the applicable part of Parsons' social system theory?

Although, as we will see in Chapters 2 and 3, both the literature and the empirical study provide indications for the relevance of Parsons' social system theory, we have to be careful with 'simply' applying that theory to the KI context (Glaser & Strauss, 1967: 34). Parsons' theory is a complex theory that is claimed to bear reference to all social actions in the society as a whole. The context of this research is different: it is not about all social actions but about KI; and it is not about society but about high-tech SMEs. Therefore, our first research question within this second phase concerns the extent to which Parsons' theory is applicable to the context of this study (RQ2a). When we answer this question we have to consider that Parsons' theory is supposed to be a whole of which we cannot simply omit parts. As shown in Chapter 4, we can and will, however, decide to focus on certain aspects while leaving other aspects out of consideration. RQ2a will be answered by elaborating on Parsons' theory and by discussing its applicability. The literature that will be used to answer this research question consists, next to Parsons' own writings, of interpretations of other scholars, including some of Parsons' students. Again, we will structure the discussion using the seven system characteristics described earlier. Since we expect that most readers are not familiar with Parsons' theory, this theory is explained in rather much detail. Also, because Parsons' theory has been heavily criticized in the last decades we spend some pages on summarizing the most important critiques and discussing the consequences for this study. In terms of design outputs, the answer to RQ2a can be considered as the conceptual design of the systemic KI model. It provides the general concepts and structure of a systemic KI model.

In the second step of this phase we go to the detailed design of the KI model (RQ2b). In this step we will use the material gathered in RQ1 and frame it into the concepts and structure of Parsons' theory. In the formulation of RQ2b (and of RQ2 in total) we have used the words 'can' and 'derived'. With the word 'can' we try to express that the design of the model is not deduced from the gathered material but requires additional creativity and imagination of the researcher. On the other hand, the word 'derived' should express that the design also is not a completely subjective activity, but is based on a substantial amount of theoretical and empirical material. The answer to RQ2b, and as such the result of Chapter 4 of this study, will be a systemic KI model.

While a full test of the systemic KI model falls outside the scope of this study – the objective of this study is to develop the model, not to test it – in the last phase of this study, the systemic KI model will be evaluated and, if necessary, improved. In this phase, we will evaluate the systemic KI model developed in the second phase against the criteria of soundness and relevance (see Subsection 1.2.2), using additional empirical material on KI. The research question guiding this phase of the study is:

3. What is the soundness and relevance of the developed systemic KI model and how should it be improved?
    a. To what extent is the model sound and how can its soundness be improved?
    b. To what extent is the model relevant for KI problem solving and how can its relevance be improved?

The criteria of soundness and relevance have been introduced in Subsection 1.2.2 and will be explained in more detail in Chapter 5. In RQ3a, the systemic KI model will be evaluated against the soundness criterion (referring to the consistency, precision, and correctness of the model). For this criterion, the systemic model will not be evaluated with additional empirical material. Rather, in this evaluation, we will mainly refer to the systematic way of developing the model in RQ1 and RQ2. Considering the emphasis on the soundness of the model in our way of developing we believe that such type of evaluation is sufficient for a model development study like this.

While the emphasis in the development process has been on the soundness of the model, its relevance has not yet been evaluated at all in the preceding two phases. Therefore, in this last phase, most emphasis will be put on the evaluation of the model against the relevance criterion (RQ3b), and in particular the manageability and the fit with the problem. For these two criteria the model will be evaluated using additional empirical KI material in the context of NPD in high-tech SMEs. Since we are to evaluate the model, we cannot use the model itself to structure our data collection. Rather, we need detailed descriptions of KI examples that are biased as little as possible. Therefore, it is important to get a 'rich picture' of KI in practice (Lee & Baskerville, 2003; Miles & Huberman, 1994). Spradley (1980) recommends highly intrusive techniques as participant observation for this type of research. However, since KI is an intangible process and not performed at one point in time, it will be impracticable, if not impossible, to use this technique successfully. Alternatively, we will use the critical incident interviewing technique (CIT, Flanagan, 1954), which is recognized as a valid, reliable, and effective method for gathering rich qualitative data for a variety of purposes, including the analysis of information behavior (Fisher & Oulton, 1999; Urquhart et al., 2003). Moreover, it has been successfully applied in SMEs across a range of business sectors (Chell, Haworth, & Brearley, 1991). Of the available interviewing techniques, the CIT is considered to give one of the most accurate and reliable retrospective reports of processes in practice. Using this technique, we will ask interviewees to elaborately describe successful and unsuccessful ('critical') examples ('incidents') of KI. Crucial for this type of interviews is that interviewees can concentrate on description and are not distracted by asking for explanations of their behavior. If explanations are needed, these should only be asked after the description. Considering that the two relevance criteria (manageability and fit with the problem) are very different, the data gathered by the CIT will be used for two different evaluations of the systemic KI model. Firstly, concerning the manageability criterion, we will step-by-step evaluate for each of the seven characteristics whether the model can and should be made simpler. Secondly, concerning the fit with the problem criterion, we will evaluate for each of the seven characteristics whether, by using the model, we are able to identify, explain, or solve KI problems that without the model are unlikely to have been identified, explained, or solved.

1.5 Thesis Outline

The remainder of this thesis is organized as follows: In Chapter 2 we provide a review of the existing literature on KI and related topics. As such, this chapter answers RQ1a. The result of this chapter is used as an input for Chapter 3, which discusses the research method and the results of the exploratory empirical study. That chapter will answer RQ1b. Together, Chapters 2 and 3 comprise the analysis phase of this study (see Figure 1.3). Based on the conclusions of this first phase of this study, and on a review of Parsons' social system theory, we develop a systemic KI model in Chapter 4. As such, this chapter answers RQ2. Subsequently, this model is evaluated and improved in Chapter 5, which describes the research method and the results of the qualitative evaluation study (RQ3). Finally, Chapter 6 discusses the achievements, limitations and implications of this study.

CHAPTER 2: ANALYSIS PART I: LITERATURE REVIEW

"The belief that there is such a thing as physics, or biology, or archaeology, and that these "studies" or "disciplines" are distinguishable by the subject matter which they investigate, appears to me to be a residue from the time when one believed that a theory had to proceed from a definition of its subject matter. But subject matter, or kind of things, do not, I hold, constitute a basis for distinguishing a discipline [...]. We are not students of some subject matter but students of problems. Any problem may cut right across the borders of any subject matter or discipline."

Popper (1963: 66-67)

"Some men seem to handle the precarious balance between [existing theory and new research] by avoiding the reading of much that relates to the relevant area until after they return from the field [...] On the other hand, some read extensively beforehand. Others periodically return to one or the other source for stimulation. There is no ready formula, of course: one can only experiment to find which style of work gives the best results. Not to experiment towards this end, but carefully to cover 'all' the literature before commencing research, increases the probability of brutally destroying one's potentialities as a theorist"

Glaser & Strauss (1967: 253).

2.1 Introduction

The purpose of this second chapter is to answer the Research Question 1a by means of a review of the current literature on KI. This research question was formulated as follows: *To what extent does the current KI literature provide sufficient theoretical and empirical material for developing a systemic KI model.* The criteria that were formulated in Subsection 1.4.2 for the material to be sufficient were 1) there should be both theoretical and empirical available for each of the seven system characteristics described in Subsection 1.2.2; and 2) this material should refer to an underlying systemic framework.

In order to answer this research question, the chapter is structured as follows: In Section 2.2 we will discuss the approach that was followed for the literature review. Subsequently, Sections 2.3 through 2.5 provide an overview of how respectively the structural, behavioral, and control characteristics of a systemic model instantiate in the KI literature. Thereafter, Section 2.6 evaluates whether the available material is sufficient for developing a systemic KI model or not. The chapter ends with a conclusion in Section 2.7. The purpose of this chapter is not to provide a complete overview of KI literature, nor to account for similarities and differences between the various fields of research that are reviewed. Rather, the goal is to gather and structure the available material that can be used to develop a systemic KI model that is able to identify, explain, and solve KI problems in practice.

2.2 Approach

In Subsection 1.3.2 we have argued that a systemic approach to KI should not be limited by the boundaries of research disciplines, because, in practice, KI is not a discipline but an interdependent set of KI activities. This statement has significant consequences for the way to conduct a literature review. Namely, most scientific journals are associated with a certain research discipline. This implies that with choosing a set of journals in advance we would automatically limit the review to certain disciplines. Tracing articles by citation analysis includes the same risk, since references usually also stay within a discipline, subdiscipline, or journal (Goldman, 1979; White & McCain, 1998). Therefore, we needed a review procedure with a high likelihood of covering multiple disciplines. For this, especially the start of the review procedure is important, since this determines to a large extent the breadth of the review. When, from its start, the review is limited to a few disciplines it is, for the reasons mentioned above, very hard to enter other disciplines. Below we will explain what procedure was followed to avoid disciplinary bias, what type of literature was collected, and how this literature was analyzed.

2.2.1 Literature Collection

We deemed the most suitable start for the literature review to be a simple keyword search. When the database used for querying covers a wide range of disciplines, this procedure will not be limited to a narrow set of disciplines. Once from this start the review covers multiple disciplines we could from there on continue with citation analysis and browsing certain journals. Below we describe the complete procedure that was followed.

Step 1: Keyword Search: 'Knowledge Integration'

The first task was to find the most suitable database (or search engine) that covered a broad range of disciplines. Since it was by far the broadest we could find, we used the meta search engine 'PiCarta' from OCLC PICA. PiCarta is a search engine that queries the catalogues of numerous scientific libraries throughout Europe and South Africa and the catalogues of publishers, including Science Direct, Swetsnet, Ideal Library, Wiley Interscience, Emerald, and Informs. Since it covers a wide range of disciplines, it was a suitable starting device for the literature review (Cooper, 1989). As this study is on KI, our obvious starting query was "knowledge integration" (including quotation marks) in the Title, Abstract, and Keywords fields. This yielded 38 results with the following characteristics:

- The retrieved articles and books were published in the following years: 2002: 3, 2001: 4, 2000: 10, 1999: 4, 1998: 6, 1997: 1, 1996: 6, 1995: 2, 1994: 2, and 1986: 1. Hence, while the databases contain numerous journals with volumes going back to the 19^{th} century, the use of the term KI seems to be clearly limited to the last decade.
- The publications on KI seem to be of two different kinds:
  - Those in areas where knowledge is an object of study, including computer science (Lee et al., 1998; Lu, 1996), information systems (Huang, Newell, & Pan, 2001), education (Eylon, 2000; Ivanitskaya et al., 2002), management (De Boer, Van den Bosch, & Volberda, 1999; Grant, 1996), and technology transfer (D'Adderio, 2001).
  - Those in areas where KI is used in a particular application area, including construction (Stuurstraat & Tolman, 1999), chemistry (Hofmeister, 1998), and environmental studies (Scholz, Mieg, & Oswald, 2000).
- Publications on KI concern the integration of knowledge from different databases, people, departments, and organizations.

The result of this first step provided only very few publications that explicitly used the term KI to refer to KI as a process of integrating external with internal knowledge. For example, while Grant (1996) mentions KI in markets and networks he concentrates on intraorganizational KI. Therefore, we proceeded with the next step.

Step 2: Keyword Search with Descriptions of Knowledge Integration

After the almost complete lack of relevant results in the first step, we had to look for another way to start a broad literature review. Still, we believed a keyword search was the most appropriate way to continue because we had not sufficient input from the first step to continue in other ways. Therefore, we continued the literature review with keyword searches that described KI. Combinations of three groups of keywords were made: 1) regarding the *external character of KI*; these are 'interorganizational', 'interfirm', and 'external'; 2) regarding the *involved object*; these are 'knowledge', 'information', and 'technology'; and 3) regarding the *activities*; these are 'integration' 'seeking' 'finding', 'acquisition', 'exchange', 'transfer', 'sharing', 'use', and 'learning'. We did not include an explicit reference to systemic models, since we expected publications to contain systemic elements without explicitly referring to systems theory. With this set of keywords PiCarta was queried again, using combinations of two groups of keywords (1 and 2, 1 and 3, and 2 and 3) and the combination of all three groups of keywords (1, 2 and 3).

This resulted in a list of hundreds of results of which many seemed irrelevant. Examples of irrelevant results were articles about 'knowledge of cultural integration', and 'enterprise application integration'. Hence, although the recall of the query was high, the precision was not. As a result of the low precision of the created sample, we had to select articles by reading titles and abstracts. This resulted in a list of relatively new and specialized articles (1993 or younger) from relatively unknown authors (unlike scholars as Grant, Hamel, Huber, Nonaka, Spender, and Weick and others).

Step 3: Linking, References, and Cross-Fertilization

During the remaining part of the research, an iterative approach was followed to find more relevant publications. The references of the publications found after step 2 were used to select additional publications on KI. While reading the selected articles, many new keywords and references were found that were used to select additional publications. Examples of new keywords were 'absorptive capacity' (Cohen & Levinthal, 1990), 'knowledge sourcing' (Gray & Meister, 2004), and 'information foraging' (Pirolli & Card, 1999). Subsection 2.4.1 (which concerns the patterning of KI activities) will illustrate this in more detail.

In order to arrive at cross-fertilization between theory and practice, we simultaneously started the exploratory interviews that are described in Chapter 3. By doing these interviews, we became better acquainted with KI in practice, which helped us again to specify new keywords. Examples are 'enquiring', 'gathering', and 'reviewing'.

2.2.2 Characterization of the Collected Literature

During the data collection of the first three steps, we collected approximately 800 publications that concerned at least one KI activity. To check whether our procedures had indeed resulted in a set of publications covering a wide range of fields, we tentatively categorized them into a number of fields. These fields are summarized below, including a number of publications in each field. The purpose of this categorization is merely illustrative, as to characterize the data. Although the categorization is very tentative, it should provide the reader with some grasp of the type of literature that was collected without having to go through the complete list of references.

Organizational Learning, Organizational Memory, and Knowledge Management

The first research field where knowledge is amongst the objects of research is that of organizational learning, organizational memory, and knowledge management. Although the three concepts differ somewhat in their emphasis, they are often used interchangeably and in close relation to each other. Examples of publications in this field are: (Argyris & Schön, 1978; Huber, 1991; March, 1991; Nonaka, 1994; Walsh & Ungson, 1991; Wijnhoven, 1999b)

Organizational Memory Information Systems and Information Systems

A second field of research where KI activities are mentioned is the field of computerized information systems. In this field we find computerized systems for organizational memories, knowledge, and information. Since this area is about information *systems*, we expect there to find systemic approaches to KI. Examples of publications in this field are: (McKeown & Leitch, 1993; Stein & Zwass, 1995; Wijnhoven, 1999a)

Information Seeking, Information Retrieval, and Information Foraging

The third research field is that of information seeking and the related areas of information retrieval and information foraging. While the roots of these areas are different (library science, computer science, and biology) they are currently hardly discernable. Examples of publications in this field are: (Belkin & Croft, 1992; Krikelas, 1983; Pirolli & Card, 1999; Spink, 2002; Wilson, 1999)

Knowledge Transfer, Knowledge Integration, and Knowledge Reuse

A fourth field is that of intra- and interorganizational knowledge transfer, integration, and reuse. This field is different from the field of knowledge management in that the latter concentrates on knowledge activities within a collective (e.g. organization) while knowledge transfer concentrates on knowledge activities between collectives. Another difference is that the knowledge management literature mainly provides models of activities and processes, while the knowledge transfer field is more concerned with the explanation of the outcomes of the transfer. Examples of publications in this field are: (Argote & Ingram, 2000; Grant, 1996; Majchrzak, Cooper, & Neece, 2004; Markus, 2001; Szulanski, 2000)

Environmental Scanning, Boundary Spanning, Information Processing, and Intelligence

While the previous four fields concern research fields that are general, that is, that discuss knowledge and information processes irrespective of the goal it is used for, this and the next fields concern research fields where there is a more specific purpose. This field concentrates on knowledge and information processes used to reduce uncertainty for the organization. In this field we find models of environmental scanning, boundary spanning, business intelligence, and information processing. Examples of publications in this field are: (Aguilar, 1967; Choo, 2001; Daft & Weick, 1984; Gilad & Gilad, 1988; Tushman & Nadler, 1978)

Technology Transfer, Absorptive Capacity, and Knowledge Brokerage

Of particular interest for the NPD context of this study is the research field of technology transfer, absorptive capacity, and knowledge brokerage. Although also the concept of boundary spanning has been applied to innovation (Tushman, 1977), technology transfer, absorptive capacity, and knowledge brokerage specifically deal with knowledge processes for innovation. Examples of publications in this field are: (Allen, 1977; Cohen & Levinthal, 1990; Hargadon & Sutton, 1997; Zahra & George, 2002)

Knowledge Intensive Business Processes

A seventh field discussing KI is that of knowledge intensive business processes. A number of authors provide models of the relationship between knowledge processes and business processes. These models are relevant for KI, since they link knowledge activities to organizational activities. Examples of publications in this field are: (Braganza, Edwards, & Lambert, 1999; Remus & Schub, 2003; Yap, Ngwenyama, & Osei-Bryson, 2003)

Research Methodology, Design Research, and Information System Development

KI is not only a topic that has received much interest in research; it also is central to doing research. In research, empirical knowledge and existing theoretical knowledge are combined into new knowledge. Information systems development is another field in which the acquisition of knowledge is of crucial importance. It is categorized in the same field since it is rather similar to design research. Examples of publications in this field are: (Glaser & Strauss, 1967; Iivari, Hirschheim, & Klein, 2004; Loucopoulos & Karakostas, 1995; Nunamaker Jr., Chen, & Purdin, 1990-91; Weick, 1989)

Information and Knowledge Supply

While the aforementioned fields were mainly concerned with the recipient side of KI, also the supply side discusses KI activities. To a large extent the activities involved may be similar; the difference is that they are performed by the supplier rather than the recipient. Examples of publications in this field are: (Meyer & Zack, 1996; Stuckenschmidt & Van Harmelen, 2005; Wijnhoven & Kraaijenbrink, 2005)

Other

In the aforementioned fields KI is close to the core of the field. Additionally, the data collection procedures have resulted in publications in a range of fields were KI is discussed in the periphery. Examples of these fields are publications on marketing (Gregan-Paxton & John, 1997), linguistics (Robinson, 1995), computer science (Wondergem, Van Bommel, & Van der Weide, 1998), cognitive science (Gaines, 2003), and problem solving (Osborn, 1953).

2.2.3 Literature Analysis

After and during the collection of the literature, the collected publications were analyzed for their contribution to each of the seven system characteristics. The following two steps summarize the analysis procedures that were followed.

Step 4: Finding System in the KI Literature

In this fourth step, this literature was examined for indications for systemic KI models. Rather than operating inductively, we used the list of system characteristics of Subsection 1.2.2 to structure this examination. As a divergent step, we first inventoried for each of the fields described in Subsection 2.2.2, what was written there for each of the seven system characteristics. Hence, we investigated within each field what was written about elements of a KI system, the boundaries of such system, and so on. Using this approach, we arrived at very different results between the fields. For example, while the level of collectiveness is deemed very important in the fields of organizational learning and organizational memory, we hardly find it back; in for example, the field of information seeking and technology transfer.

Step 5: Consolidation

Since we were not interested in comparing the several fields or publications, but in the development of a systemic KI model, the final step was what we may call a 'cross-case analysis'. In this converging step we left the fields for what they were and aggregated their results for each of the system characteristics of Subsection 1.2.2. For some of the characteristics we observed that what was said in one field also could have been said in another field. Consequently, we went back to that other field to specifically look whether there was also said something about that characteristic. Occasionally this was the case. In this way, we improved the recall of systemic elements within the collected publications. Finally, for each system characteristic, we aggregated the several views that were collected from the several fields. The results are described in the following sections.

2.3 System in the KI Literature: Structural Characteristics

The first type of system characteristics that we present are the structural characteristics of a KI system. Put simply, these characteristics account for what the system *is*. In Section 2.4 we will discuss the behavioral characteristics, which account for what the system *does*. Finally, in Section 2.5 we will discuss the control characteristics. These account for what the system *should be or do*. Of course, in practice these cannot be separated. For example, the structure of the system affects its behavior and vice versa. However, for analytical reasons we can and will separate them. As presented in Subsection 1.2.2, the structural characteristics include the elements of a KI system (Subsection 2.3.1), the boundaries of a KI system (Subsection 2.3.2), and the internal structure of a KI system (Subsection 2.3.3).

2.3.1 Elements of a KI System

In Subsection 1.2.1 it was argued that a KI system is an aspect system. As discussed there, this means that a KI system is a system consisting of actors and technology performing KI activities on knowledge that resides in a system consisting of actors, technology, and activities. In this subsection, we will discuss how each of these elements appears in the current KI literature and what this means for modeling KI.

Knowledge

Although there seems to be common agreement nowadays that knowledge is crucial for organizations (Drucker, 1992; Lam, 2000; Quinn, 1992), there is less agreement on the question what knowledge is. Given the numerous definitions and taxonomies of knowledge, this is certainly not a trivial question (e.g. Alavi & Leidner, 2001; Boersma & Stegwee, 1996; Boisot, 1995; Choo, 1998; Nelson & Winter, 1982; Nonaka, 1994; Spender, 1996b; Stein, 1995; Winter, 1987; Zander & Kogut, 1995). We will not try to provide a definite answer to this question. Rather, we will present the taxonomy of knowledge that follows from the conceptualization of KI as an aspect system and discuss how it is reflected in the current KI literature. Thereafter, we will discuss how this taxonomy relates to three of the currently popular taxonomies.

Systemic Taxonomy of Knowledge

In Subsection 1.2.1 it was suggested that when a KI system is considered as an aspect system it can be argued that there are four types of knowledge: knowledge in actors, in technology, in activities, and in the system of their interconnections. Before further specifying each of them, we want to remark that there are similar taxonomies in the KI literature. For example, Argote and Ingram (2000) distinguish between three types of knowledge reservoirs (members, tools, and tasks) and networks of combinations of these three types. When we compare their terminology to ours, it is easy to see that members correspond with actors, tools with technology, tasks with activities, and networks with systems. Another example is Walsh & Ungson's (1991) discussion on the retention media of organizational memories: according to them, knowledge resides in individuals, transformations, ecology (the physical setting in an organization), culture, structure and external archives. In terms of the systemic taxonomy of this study, individuals correspond to individual actors, transformations to activities, ecology to technology, and culture and structure to system. The last retention medium, external archives, is not different from the other five except for that it resides outside the focal system. Wijnhoven (1999b) adds a seventh retention medium to Walsh & Ungson's media: information technology. On the one hand, this can be seen as a special type of technology. However, in accordance with Wijnhoven, we believe that the role of information technologies in a KI system is to such a large extent different from other types of technologies that it should be considered as another type of system element. This difference will be further explained below. Summarizing the preceding discussion on a systemic taxonomy of knowledge, we distinguish knowledge in actors, in information technology, in non-information technology, in activities, and in the system of their interrelationships. Each of these is discussed below.

Knowledge in actors: A first type of knowledge in a systemic taxonomy is knowledge that resides in the actors of the system. As such, knowledge is considered as a characteristic of the individual actors in the system. This view is adopted in, for example, the literature on individual and organizational learning and in literature focusing on human capital (Argyris & Schön, 1978; Kim, 1993; Kolb, 1984; Senge, 1990). It is also essential in the development of information systems and knowledge management strategies that are meant to find experts rather than their expertise (Hansen, Nohria, & Tierney, 1999).

Knowledge in information technology: A second type of knowledge is knowledge that resides in information technologies, or more specific, that is represented in information technologies. Information technologies are not limited to computers but include, for example, paper documents, voice recorded tapes, and diagrams. Although the focus on its virtual rather than its physical character might make us think differently, information technology is, like any other technology, something physical. The difference between information technologies and other technologies is that the first contain 'verbally encoded knowledge' and the latter contain 'physically encoded knowledge' (cf. Allen, 1977). Information technologies encode knowledge using a language, while other technologies encode knowledge without such language. Knowledge that resides in information technologies can be regarded as an object going through the phases of input, throughput, and output of the system. As such, the role of knowledge is that of a resource which can be manipulated, stored and disseminated in the system. This role is adopted in large shares of the literature on, for example, knowledge management (e.g. Gold, Malhotra, & Segars, 2001; Nissen, Kamel, & Sengupta, 2000), organizational memory (Stein, 1995; Wijnhoven, 1999b), and information seeking (Krikelas, 1983; Spink, 2002; Wilson, 1999).

Knowledge in non-information technology: A third type of knowledge is knowledge that resides in non-information technologies. That knowledge can be embedded in this type of technologies is recognized in, for example, the literature on NPD (Becker & Zirpoli, 2003; Madhavan & Grover, 1998) and literature on knowledge transfer between production shifts using the same technology (Epple, Argote, & Devadas, 1991). This is also subject of some of the literature on research methodology. An example is ethnography, where the physical characteristics of a situation are an important input for the researcher (Spradley, 1979).

Knowledge in activities: Fourthly, knowledge can be considered as part of the activities that are performed in the system (Alavi & Leidner, 2001). In this role, knowledge is a process of simultaneously knowing and acting (Zack, 1998). As such, knowledge is embodied in actions (Blackler, 1995) and concerns how to perform these actions (Kogut & Zander, 1992). That knowledge is embedded in activities is recognized in, for example, the literature on experiential and vicarious learning where learning respectively takes place by performing an activity or by observing somebody else doing this activity (Anzai & Simon, 1979, Kolb, 1984, Gioia & Manz, 1985). It is also recognized by Nelson & Winter when they emphasize that organizations 'remember by doing' (Nelson & Winter, 1982).

Knowledge in system: Finally, knowledge can be considered as residing in the system that is comprised of the four elements described above. Walsh & Ungson (1991) seem to refer to this type of knowledge when they identify culture and structure as retention media of knowledge. In these media, it is not a particular element of the system in which knowledge resides. Rather, it is a collection of elements with interconnections in which knowledge resides. That knowledge resides not only in elements of the system but also in the system itself also is recognized by Argote & Ingram (2000) who consider networks of system elements as important reservoirs of knowledge. Other ways in which scholars refer to this last type of knowledge are system dependent knowledge (as opposed to system independent knowledge (Winter, 1987)) and background knowledge (Spender, 1998).

Relation to Some Popular Taxonomies

As remarked several times above, the taxonomy of knowledge that follows from considering KI as an aspect system is not entirely new. However, this taxonomy also is not widely adopted. Rather, there are a number of taxonomies of knowledge that seems to be more popular. Below we will discuss three of them and relate them to the taxonomy adopted in this study.

Tacit vs. Explicit Knowledge: The first and probably most wide-spread taxonomy of knowledge is the distinction between tacit and explicit knowledge. Put simply, the distinction is often characterized by what has become a catchphrase in the field of knowledge management: 'we can know more than we can tell' (Polanyi, 1966). Explicit knowledge, then, is the knowledge that we can tell, and tacit knowledge the knowledge that we cannot tell. Concerning this distinction, there is an ongoing discussion between followers of Nonaka (1994) – who characterize them as two ends of one dimension – and followers of Polanyi (1966) – who characterize them as two distinct dimensions. We believe the discussion is mainly fed by confusing the knowledge objects to which is referred and not by an actual disagreement between both authors. Polanyi speaks of 'tacit knowing' and refers to knowledge as a holistic concept. On this level, tacitness can be seen as a dimension. Nonaka, on the other hand, speaks of tacit 'knowledge' and refers to smaller chunks of knowledge that can be either more explicit or more tacit. Around the distinction between tacit and explicit knowledge more discussions and confusions have taken time and energy of researchers. One persistent confusion is that explicit knowledge is sometimes – mistakenly in our view – used as a synonym for represented knowledge (e.g. Binney, 2001). In terms of Polanyi's phrase, explicit knowledge is knowledge that can be represented (it can be 'told') and represented knowledge is knowledge that is represented (it is 'told'). Another popular term for explicit knowledge is 'codified knowledge'. When we consider how Boisot has conceptualized codification, this seems a correct labeling: codification "[...] creates perceptual and conceptual categories that facilitate the classification of phenomena" (Boisot, 1995: 42). Hence, it explicates knowledge that was previously tacit. However, confusion arises again when scholars use the term codification also when they refer to represented knowledge (Hansen, Nohria, & Tierney, 1999).

While Polanyi has introduced the term 'tacit', the concept itself is much older. It has, for example, been recognized by Hayek (1945) and Ryle (1949). Ryle's distinction between 'knowing that' and 'knowing how' is of particular interest here because we believe it helps to better understand the differences between explicit and tacit knowledge. Put simply, 'knowing that' refers to that what we can preach, while 'knowing how' refers to that what we can practice. As such, 'knowing that' is associated with facts, beliefs, theories, and truths, and 'knowing how' with skills, capabilities, and capacities. ´Knowing that' is purely dichotomous: you either know something or you don't. Ryle explains this as follows: "We never speak of a person having partial knowledge of a fact or truth, save in the special sense of his having knowledge of a part of a body of facts or truths. A boy can be said to have partial knowledge of the counties of England, if he knows some of them and does not know others. But he could not be said to have incomplete knowledge of Sussex being an English country" (Ryle, 1949: 57). On the other hand, Ryle continues to argue, "[...] it is proper and normal to speak of a person knowing in part how to do something, i.e. of his having a particular capacity in a limited degree. An ordinary chess player knows the game pretty well but a champion knows it better, and even the champion has still much to learn" (ibid: 58). When we compare Ryle's taxonomy to Polanyi's taxonomy, 'knowing that' is similar to explicit knowledge and 'knowing how' to tacit knowledge. What we hope to have illustrated with this comparison is that tacit knowledge is not just 'vague knowledge' that needs to be explicated, but is associated with knowledge embedded in what we do and not with knowledge about facts.

When we compare Ryle's taxonomy to the systemic taxonomy of knowledge of this study, there is no one-to-one correspondence between the two taxonomies. However, not all system elements are equally well-equipped to host 'knowing that' and 'knowing how', which implies that there is some relation. As we can directly take from Ryle, *actors* possess both types of knowledge. There is, however, a difference in the way both types are exposed to the outside world. Knowledge of the 'knowing that' type can be 'told' to other actors. Because it is explicit, it can be expressed in a language. This means that it can be exposed by *information technologies*, like computers and paper. Additionally, some forms of 'knowing that' also can be exposed by '*non-information technologies*', like machinery and equipment. For example, when you observe a bicycle, you see *that* it consists of two wheels, a frame, a saddle, etc. Technologies, however, cannot expose knowledge of the 'knowing how' type. Although technologies can enable and constrain our activities, there is no 'knowing how' in them of how to perform these activities. This can be understood by an example of mastering a particular skill. Consider painting: you cannot master the skill of painting by observing a painting or by reading a painting manual. When you observe a painting, you can find out, for example, what type of paint is used, what colors, and what type of canvas. This is knowledge of the 'knowing that' type. Also, by additionally reading a painting manual, you still cannot master the skill. From the manual you might learn, for example, what painting techniques exist, but this is again knowledge of the 'knowing that' type (this is obvious when we consider that this knowledge is 'told' by somebody else and thus can only be of the 'knowing that' type). The skill of painting, however, can only be acquired by observing somebody else that is painting and by doing the painting yourself (or imagining that you are doing it, cf. Ryle 1949). This suggests that in addition to actors, 'knowing how' can only reside in *activities*. Finally, since knowledge as a system comprises the four types of elements and their interrelationships it follows that a system can host both types of knowledge.

Individual vs. Collective Knowledge: A second popular taxonomy of knowledge is the distinction between individual and collective knowledge (e.g. Hedlund, 1994; Lam, 2000; Spender, 1994). The notion of collective knowledge is currently used to refer to at least two different things. In its first use, collective knowledge refers to knowledge that is shared by more than one person. This notion of collectiveness is core to some literature on knowledge sharing (Hansen, 2002; McLure Wasko & Faraj, 2005). In its second use, collective knowledge refers to knowledge that resides within the collective and not in individual elements. Using the image of a jigsaw puzzle, Galunic & Rodan nicely characterize the difference between the two by distinguishing distribution and dispersion as two distinct forms of diffusion: "A picture on a jigsaw puzzle is distributed when each person receives a photocopy of the picture. The same image would [...] be dispersed when each of the pieces is given to a different person" (1998: 1198). Collective knowledge as dispersed knowledge is knowledge that resides in the system as a whole; as opposed to individual knowledge, that resides in elements of the system. Individual knowledge can be brought into action by individuals, while collective knowledge is located in patterns of behavior and social relationships (Spender, 1994; Weick & Roberts, 1993). This distinction between individual and collective knowledge also can be found in typologies of innovations where it is referred to as component knowledge and architectural knowledge (Henderson & Clark, 1990).

When compared to the systemic taxonomy of knowledge, individual knowledge refers to knowledge in individual actors, technologies, and activities, while collective knowledge resides in a system of these elements.

Personal vs. Impersonal Knowledge: A final taxonomy that is used to characterize knowledge, and that we discuss here, is the distinction between personal and impersonal knowledge (although scholars not necessarily use these terms to make this distinction). Put simply, impersonalized knowledge is made person-independent by putting it on some carrier. From research on semiotics (Ogden & Richards, 1949; Sowa, 2000; Stamper, 1973), we observe that knowledge can be impersonalized through representations (e.g. a 100-page construction plan for a new office building) or objects (e.g. ancient construction knowledge embedded in the construction of pyramids). This distinction corresponds to the aforementioned distinction between information technologies and non-information technologies.

The use of representations has received much attention in fields like information systems, information science, and also knowledge management. Moreover, that there are various levels of impersonalization through representations is at the heart of media-richness theory, which classifies, for example, face-to-face contact as a personal medium, and a written document as an impersonal medium (Daft & Lengel, 1984; Daft, Lengel, & Trevino, 1987). Despite of the wealth of publications on the use of representations, the fact that information is representations of knowledge and not knowledge itself is hardly addressed in these fields (Carlile & Rebentisch, 2003). Sometimes these fields tend to forget that "we can represent knowledge, but the representations are not knowledge itself, no more than a map is the territory it describes" (Clancey, 1993: 33).

That knowledge can be impersonalized in objects was discussed above in the paragraph on non-information technologies. This kind of impersonalized knowledge is used, for example, in reverse engineering, technology transfer, and action research. It is remarkable that, opposed to representations, for this kind of impersonalized knowledge, scholars do seem to recognize that it is impersonalizations of knowledge and not knowledge itself. As some engineers put it in a study by Tyre & Von Hippel "There is so much information in the machine [that] it takes a very specialized skill to absorb it" (1997: 78).

In terms of the systemic taxonomy of knowledge of this study, personal knowledge refers to knowledge residing in actors and impersonalized knowledge refers to knowledge in technologies. Also, since activities are performed by actors and since the knowledge that is needed to perform them resides in actors, activities are associated with personal knowledge. Finally, since knowledge in the system resides in a collection of actors, technologies, and activities, this knowledge is both personal and impersonal.

KI Activities

After these elaborations on the concept of knowledge as the object of a KI system, we can move on to the second and core element of a KI system: KI activities. As mentioned in Subsection 1.2.1, KI activities are those activities of which knowledge is the object. Hence, these activities change some property of knowledge.

The review of the approximately 800 publications on KI and related topics yielded a collection of numerous KI activities on several abstraction levels. For example, they range from broad concepts as knowledge transfer (Argote & Ingram, 2000; Argyris & Schön, 1978; Kim, 1993) and knowledge application (Pentland, 1995) to narrow concepts as chaining (Ellis & Haugan, 1997) and indexing (Anderson & Pérez-Carballo, 2001).

A detailed discussion on KI activities is postponed to Subsection 2.4.1, where we discuss the differentiation and patterning of activities. Moreover, Appendix I provides a long list of KI activities that were found in the reviewed literature. To avoid repetitions at that place, we do not include a list of activities at this place.

Actors

KI activities are performed by actors. As we have seen in Subsection 1.2.1, in social systems, actors can be identified by the roles they play in the system. In the particular context of this study, KI and NPD in high-tech SMEs, these roles include researcher, developer, engineer, marketeer, and manufacturer. While these roles refer to the NPD process, actors also play particular roles in the KI aspect system. Based on the conceptualization of a KI system in Subsection 1.2.1, we can identify three types of roles that are discussed in the KI literature: 1) the role of the actor in the focal KI system, 2) his role towards the environment of the KI system, and 3) his role towards the controlling organ of the KI system.

Concerning the first type of role, throughout the literature we found three views on the roles that individuals play within organizations. The first view stems from gatekeeper theory (Allen & Cohen, 1969; Tushman, 1977) in which *individuals are representatives* that identify and acquire knowledge for the organization. This view is also central in the early information processing perspective presented by, for example, Daft & Lengel (1984) and Weick (1969), in which a manager's task is to reduce equivocation within the organization. In this view the individual and the collective level are unified. To the environment, the individual acts as being the organization. Although this view might well reflect the usual situation in hierarchical organizations, the other extreme could exist in organizations of professionals

(Mintzberg, 1979). In such organizations, *individuals are professionals* that identify, acquire, and then utilize knowledge themselves. In this view, autonomous individuals that are fully responsible for their own work can execute their activities. In between these two extremes, there is a third view, which emerges when considering that KI activities often cut across business processes and organizational units. Knowledge that is identified, acquired, and applied in one business process or unit can also be used within another business process or unit. This occurs, for example, in NPD, where knowledge acquired and used by a production department is also used in the development of a new product by an R & D department. In this view, *individuals are specialists* that possess different areas of expertise.

Concerning the second type of roles, individuals' roles towards the environment, the most obvious roles are that of knowledge source and recipient. When we consider a focal KI system, this system selectively receives knowledge from its environment and integrates it. In her work on knowledge reuse, Markus (2001) distinguishes four different roles of knowledge reusers. Since these roles also concern the relation between a source and a recipient (the reuser) of knowledge, we believe these roles also apply to KI. The first role of knowledge reusers is that of shared work producers. In this role, source and recipient work together in a team. This is the case, for example, in a design team where individuals of different firms work together on the development of a new product. The second role is that of shared work practitioners. In this role, source and recipient perform similar work in different settings. This is typical in communities of practice. The third role is the role of expert-seeking novices. In this role, the recipient is a novice that has an occasional need for knowledge of an expert (the source). An example is the use of a helpdesk. Finally, Markus distinguishes the role of secondary knowledge miners. In this role, the recipient develops new knowledge based on existing knowledge of the source. An example is a researcher reviewing a lot of literature and trying to abstract a new theory from it. While these four roles refer particularly to the work context of people, in their relation to the source, people also take other roles. Examples are the roles of friends, former colleagues, or fellow students of a source of knowledge (Smeltzer, Fann, & Nikolaisen, 1988; White, Bennett, & Shipsey, 1982). In the particular context of this study, some people play a role as academic towards their sources (Rosenbloom & Wolek, 1967). Because of their close relation to science, employees of science-based firms also may operate in the academic realm. For example, while developing a new product for a firm, they might use their academic contacts to find relative scientific information.

Concerning the third type of role, it was remarked in Subsection 1.2.1 that systems sometimes can take a role as target system (TS) and sometimes as controlling organ (CO). This also applies to actors. In some cases, an actor is being controlled by somebody else, while in another case the roles are exchanged. Traditionally, the roles of controlled and controlling actors are associated with respectively workers and management. This view is reflected, for example, in Wijnhoven's (1995) work on organizational learning and control systems in machine bureaucracies and in cybernetics (Beer, 1971). However, these roles also have been applied to sources and recipients of knowledge. For example, Ariely (2000) has analyzed how advertisers can influence consumer's decision making and preferences by controlling the flow of information to consumers.

There are probably more ways to characterize the role of actors in a KI system. However, since our objective is to develop a systemic model in which the relations between elements is of crucial importance, we have limited the discussion to the relation that actors have with other actors inside and outside the focal system and to the relation between actors in the controlling system and the target system.

Technology

The final element of a systemic KI model is the technology that is used to perform KI activities. In the discussion on knowledge as a system element it was discussed that knowledge resides in information technologies and in non-information technologies. Additionally, technologies also are used to perform the KI activities. This is obvious for information technologies: we use computers, for example, to search for knowledge on the Internet and to exchange knowledge by e-mail. These technologies do not only enable our KI activities, they also change them, which has been the focus on some work on the use of network technologies for communication (e.g. Castells, 1996; Schultze & Orlikowski, 2004). It does not need further explanation that searching, communicating, and storing knowledge is different when we use traditional information technologies (card indexes, letters, and paper files) than when we use computers.

Also non-information technologies enable and affect KI activities. For example, we are using cabinets to store our books, a desk on which we 'organize' our documents, and a room with an overhead projector to disseminate our findings to colleagues. While, in general, the role of such technologies is researched in the socio-technical systems research (see Subsection 1.2.1), we are not aware of any publication in the reviewed fields that explicitly addresses the effect on KI activities. From the examples mentioned above, it is however evident that non-information technology can substantially affect KI activities.

Consequences for KI

While this subsection only has addressed the first of seven characteristics of a KI system, we can already see that what was said about the elements of a KI system substantially affects how we perceive KI. First of all, with the taxonomy of knowledge discussed in this subsection, we can now provide a more concrete picture of what it means to integrate knowledge. The taxonomy shows that when we want to integrate knowledge, this involves the integration of knowledge residing in four different types of system elements (actors, (non)-information technologies, and activities) into a system of knowledge. Or, in a somewhat more complex form, integrating knowledge means that a system of knowledge has to be integrated into another system of knowledge. This is the case, for example, when one company takes over another company and wants to integrate this other company into its own company. This conceptualization of KI is different from (though not necessarily incompatible with) the probably most well known conceptualization of KI by Grant, who focuses on the integration of knowledge from different specializations. The taxonomy of knowledge also shows that the integration of one type of knowledge will be more difficult than the integration of other types of knowledge. For example, knowledge that resides in the separate elements of a system is easier to identify, transfer, and transform than knowledge that resides in a system of these elements.

Concerning the KI activities, this subsection has not yet provided much detail; this is postponed to Subsection 2.4.1 in which patterns of KI activities are discussed. However, we can already conceive that the taxonomy of knowledge also has consequences for the type of KI activities that are performed within a KI system. The five different types of knowledge that were identified will ask for different KI activities. For example, transferring knowledge that resides in an individual actor's brain is different from transferring knowledge that is written down in a document.

Concerning actors as elements of a KI system, we can see that different roles are associated with different distributions of work within a KI system. For example, a KI system in which all individual actors work as professionals and acquire their own external knowledge will be different from a system in which representatives of the system acquire external knowledge and disseminate this to others within the system. Also in relation to the environment the roles of actors affect the KI activities that are to be performed. For example, when source and recipient are shared work producers, they operate within the same context. In this case, the recipient can probably apply knowledge from the source without many problems. On the other hand, an expert-seeking novice will have much more difficulty understanding what his source is talking about and to apply his knowledge. In the discussion on control, we have seen that actors sometimes can take the role as controlling organ and sometimes as a target system. This also has consequences for the activities that are performed. For example, when in the role of controlling organ, somebody is performing activities by which he is trying to influence somebody, which are completely different from KI activities by which he is integrating knowledge.

Finally, concerning technology as system element, we see that KI activities are performed differently when the technology that is used is different. Since this was illustrated both for information technology and for non-information technology, we will not provide examples here. Rather we will move on to the next characteristic of a KI system: its boundaries.

2.3.2 Boundaries of a KI System

The second structural characteristic a KI system is its boundaries. System boundaries define what is considered to be internal to a KI system and what is considered to be external to a KI system (the environment, or 'supersystem'). There are three aspects of system boundaries that have gained attention in the current KI literature. These are the location of the boundary of a KI system, the character of this boundary, and the origin of this boundary. This subsection elaborates on what has been written in the current KI literature on each of these three aspects of the boundaries of a KI system.

Location of Boundaries

In order to describe the boundaries of a KI system, we can use each of the system elements discussed in Subsection 2.3.1. In the reviewed KI literature, the most common way to do so is by describing the actors of the system. In the various research fields we find a variety of the level of aggregation at which system boundaries are set.

The smallest system that we find is that of an individual actor interacting with another individual actor or with technology. Examples are situations where two individuals communicate, or individuals interact with computer systems. This type of system is found in the literature on, for example, information seeking and retrieval (e.g. Bates, 1979; e.g. Belkin & Croft, 1992; Ellis & Haugan, 1997; Krikelas, 1983; Xie, 2002), and data collection techniques in research methodology (Cooke, 1994; Flanagan, 1954). On a higher level of aggregation we find systems at the level of groups. Examples are knowledge sharing in teams (Majchrzak et al., 2002), knowledge creation in groups (Leonard & Sensiper, 1998), and knowledge integration in virtual teams (Alavi & Tiwana, 2002). Another way of defining system boundaries at this level of aggregation is by focusing on organizational departments. For example, in his work on technology transfer, Allen (1977) considers the boundaries of the system to be the boundaries of the 'technology' function in a firm, (the engineering department). This way of locating boundaries is also used in literature on knowledge transfer and integration between R&D and marketing departments (Gupta, Raj, & Wilemon, 1985; Moenaert & Souder, 1996). At a level higher, we find systems where the boundaries are located at the level of organizations. Usually these include a number of departments consisting of a number of individuals. This location of system boundaries is most common in the fields of organizational memory, organizational learning, and knowledge management (Huber, 1991; Kim, 1993; Walsh & Ungson, 1991; Wijnhoven, 1999b) and the fields of environmental scanning and information processing (Choo, 2002; Corner, Kinicki, & Keats, 1994; Daft & Weick, 1984; Tushman & Nadler, 1978). Some authors go beyond the organization as a system and consider dyads and networks of organization as a system. Examples are in the field of knowledge transfer in alliances (Hamel, 1991; Larsson et al., 1998; Soh, 2003), knowledge management in virtual organizations (Blecker & Neumann, 2000) and knowledge networks (Boari & Lipparini, 1999; Dyer & Nobeoka, 2000; Groen et al., 2002; Kogut, 2000; Van Baalen, Bloemhof-Ruwaard, & Van Heck, 2005). Finally, there are authors who analyze society as a system. An example is Hayek (1945), who discusses the use of knowledge in society. Also Castells (1996) considers systems at this level of aggregation.

Character of Boundaries

Subsection 1.2.1 has mentioned two characteristics of system boundaries that characterize an open social system: permeability and stability. We have argued that social systems are open systems that interact with their environment. Hence, their boundaries are permeable. In most of the fields reviewed in this study this is explicitly acknowledged. Particularly in the fields of, for example, information seeking, environmental scanning, information processing, boundary spanning, and absorptive capacity much attention has been given to the openness of the system: these fields elaborately analyze the way systems import knowledge from their environment. Also in action research (Spradley, 1980), system boundaries are assumed to be permeable. By switching between his role as observer and his role as participant, the action researcher is constantly crossing the boundary between the action system and the research system. In other fields, quite often, the link of the system with its environment is not mentioned or simplified to a single connection. An example of the latter is in the fields of organizational learning and memory, where the link to the environment is sometimes instantiated as the acquisition of knowledge from the environment (Huber, 1991; Walsh & Ungson, 1991; Wijnhoven, 2003). An example of a field where the link of the system with its environment has received little attention is that of knowledge management. With some exceptions (e.g. Wiig, De Hoog, & Van der Spek, 1997), this field has concentrated on the internal aspects of a system (Alavi & Leidner, 2001; Nissen, Kamel, & Sengupta, 2000; Pentland, 1995).

A second aspect to characterize system boundaries is their stability. With only very few exceptions we can observe that all of the reviewed fields consider – either implicitly or explicitly – the boundaries of the system under study to be stable. Without giving specific references, we see that in these fields, the boundaries of the system are determined in advance and considered to be unaffected by the process under study. An exception is literature on the transfer and integration of knowledge in mergers and acquisitions (Bresman, Birkinshaw, & Nobel, 1999; Empson, 2001) where the boundaries of the system are extended by incorporating another firm. Another exception is literature on knowledge brokerage in which a knowledge broker is gradually building a network by linking previously unconnected actors (Hargadon, 2002).

Origin of Boundaries

In theory, KI system boundaries can be determined by every imaginable aspect of a KI system. Hence, rather than trying to provide a full account of possible ways to define system boundaries, we provide those ways that were most used in the reviewed KI literature.

The first and most common way of defining the boundaries of a KI system is by – explicitly, but more often implicitly – considering them identical to the organizational boundaries. With organization here is meant the formal organization that is established by legal contracts. Examples are research on organizational learning in small firms, where the system boundaries are similar to that of the small firm (Chaston, Badger, & Sadler-Smith, 2001); and research on knowledge flows within multinationals where the system boundaries are similar to that of the multinational (Gupta & Govindarajan, 2000). Also at the intraorganizational level, the formal organization is often copied for the defining of KI system boundaries. Hence, if the organization is organized by function (e.g. engineering, marketing, manufacturing), output (e.g. product line 1, product line 2), or customer (e.g. public, business, private) (Nadler & Tushman, 1988), the system boundaries are defined accordingly. Examples are respectively (Shuchman, 1981), (Ramesh & Tiwana, 1999), and (Lord & Ranft, 2000).

Another way of determining system boundaries is by a common physical object that is used for the input, throughput, or output of the system. We find this, for example, in the literature on information systems (development), information retrieval, and regional networks. An example is the use of intranets as a means to support knowledge work. Extending the work of Choo, Detlor, & Turnbull (2000), Stenmark (2001) suggests that intranets play a role as information space, awareness space, communication space, and collaboration space. By defining the space, the intranet also sets the boundaries of the system under study. Another example is in information retrieval where the retrieval system determines the boundaries of the system, i.e. the concerning information technology and its users. A final example is in the field of regional networks, where the physical proximity is used as a means to define the boundaries of a system (Almeida & Kogut, 1999).

A third way of defining boundaries of a system is by taking into account the common interest and/or knowledge of a group of individuals. This view on system boundaries is adopted, for example, in the knowledge based theory of the firm, where the boundaries of a firm are assumed to derive from the activity system of knowledge production and application

(Spender, 1996a). Also in other fields we find similar ways of defining system boundaries. Examples of this are a dispersed team working together towards the common interest of solving a problem (Majchrzak et al., 2002), and KI in cross-functional projects (Huang & Newell, 2003). Also the development of Linux software can be considered as an example where the boundaries of the system are not defined by legal organizational boundaries, but by a common interest in developing more successful software (Lee & Cole, 2003). A final example is communities and networks of practice, where individuals share a common expertise or skill, either as a pre-condition, or as a result of their connectedness (McLure Wasko & Faraj, 2000; Van Baalen, Bloemhof-Ruwaard, & Van Heck, 2005).

A fourth way of defining system boundaries is by considering the activities that are performed. Regarding business activities in general, this is done, for example, in a functional organization structure (see above). This also can be done by leaving the organization structure and looking at KI activities instead of business activities. This is done, for example, by Wijnhoven & Kraaijenbrink (2005) when they suggest five roles in information markets, networks, and hierarchies: the information service, the supplier, the customer, the sponsor, and the subcontractor. Although the labels that are used also are used to refer to formal organizations, they refer to roles that can be instantiated both within a single organization, by various organizations, or by individuals. Another field where activities are used to define the system boundaries is that of research methodology. When describing a research methodology, it is the activities that are described and that define what is part of the research and what is not.

Consequences for KI

As this subsection has illustrated, there are different views on the location, character, and origin of KI system boundaries in the current literature. It seems that the most dominant view is a view in which the boundaries of a KI system are set in advance along the boundaries of the formal organization and are assumed relatively stable for the period under consideration. From the systems theory perspective outlined in Subsection 1.2.1, however, we can see that this dominant view is not in line with some of the fundamentals of systems theory:

- The boundaries of a KI system are not stable unless we consider the KI system only in a short time period;
- The boundaries of a KI system depend on the aspect under consideration, in this case knowledge. This implies that the boundaries of a KI system are not automatically identical to the boundaries of the formal organization.
- The boundaries of a KI system are a result of patterns of activities. Thus, a boundary should not be predefined, but should be considered as dependent of the activities in the KI system.

Since the dominant view on system boundaries departs so much from these fundamentals, we will not adopt this view in this study. Rather, concerning this characteristic of a KI system, we turn to those other views presented in this subsection that are more compatible with systems theory. In particular Spender's view on the boundaries of a KI system well fits the fundamentals of systems theory. This is not surprising since Spender applies a systems theory perspective in his paper. From Spender's work and from the outline of a KI system in

Subsection 1.2.1, we adopt a view of KI system boundaries in which these boundaries are open, changing, and dependent on the patterns of KI activities that emerge in the course of time. This view will be further specified in subsequent chapters.

2.3.3 Internal Structure of a KI System

We have discussed the elements and the boundaries of a KI system in Subsections 2.3.1 and 2.3.2. The final structural characteristic that we discuss in this subsection is the internal structure of the system, which indicates how the elements are organized within the system boundaries. As discussed in Subsection 1.2.1, a KI system is a hierarchical system. This suggests that there are two dimensions of system structure: levels of aggregation and functional subsystems. In systems theory, the supposed relation between the two is that subsystems can be distinguished at each level of aggregation. Additionally, as also discussed in Subsection 1.2.1, KI target systems (TSs) at each level of aggregation are controlled by their own a controlling organs (COs). This distinction between COs and TS comprises a third dimension of KI system structure.

Before we elaborate on what the current KI literature mentions about these two dimensions, it is useful to remark that a considerable share of the KI literature considers KI as a black box. This literature focuses on the inputs, outputs, or changes to the system, rather than on its internal structure. An example is De Boer, Van den Bosch, & Volberda (1999) who analyze the effect of organizational form and combinative capabilities on KI efficiency, scope, and flexibility. Another example is Lane & Lubatkin (1998) in their analysis of the effects of partner similarity on interfirm learning. While more examples exist, we will now focus on the three dimensions of the structure of a KI system: levels, subsystems, and control.

Levels of Aggregation

A way in which the literature is concerned with the structure of KI systems is by distinguishing several levels of aggregation. Subsection 2.3.2 already discussed levels of aggregation in relation to system boundaries. Here we focus on aggregation levels within a system. Examples of models in which at least two system levels are distinguished abound in the KI literature. In particular the literature on organizational learning and information processing provides a rich picking for such models. In its simplest form these models discern the individual and the organizational level. One basic model is that of Hedberg (1981) which suggests how individual and organizational learning affect each other. Other examples in the field of organizational learning in which these two levels are distinguished are (Argyris & Schön, 1978; Hedberg, 1981; Kim, 1993; March, 1991; Spender, 1994). An example in the field of information processing is Corner, Kinicki, & Keat (1994) who provide an integrated model of organizational and individual information processing. A somewhat different example concerning these two system levels can be found in the early information processing literature (Daft & Lengel, 1984; Weick, 1969), in which individual managers' tasks are to reduce equivocation within the organization. Finally, also in the literature on learning and knowledge sharing in groups two system levels are distinguished. An example is Alavi & Tiwana's (2002) work on KI in virtual teams.

In addition to the majority of KI literature that concerns one or two system levels, there are publications distinguishing more levels. For example, Crossan, Lane, & White (1999) distinguish three levels (individual, group, and organization) when they describe organizational learning as a dynamic process. In his work on 'knowledge management in the N-form corporation' Hedlund (1994) adds to this the interorganizational level, resulting in a four-level model of a system.

Functional Subsystems

It is assumed in systems theory that within a system, at each level of aggregation, functional subsystems can be distinguished. The simple idea behind this is that, at a certain level, one subsystem will not perform all necessary activities at that level, but will specialize on particular activities. In other words, there is a division of labor amongst the subsystems. The patterns of activities that emerge from this division of labor comprise the function of a subsystem.

As also was the case for system boundaries, in the literature, subsystems are sometimes defined using the formal organizational boundaries. This is done in, for example, research on the interface between the R&D and Marketing department (e.g. Gupta, Raj, & Wilemon, 1985). Since this study concerns the KI aspectsystem, we will, however, focus on those subdivisons in subsystems that are made from a KI perspective. When we scrutinize the current KI literature, there appear two ways in which subsystems are identified: based on the effect that KI activities have on knowledge (knowledge functions), and based on their effect on the system (system functions). In the first case, subsystems consist of KI activities that are *similar*. For example, they consist of multiple KI activities that lead to the acquisition of knowledge. In the second case, subsystems consist of various KI activities that are *complementary*. In principle, both types of functions could be used to decompose a system into subsystems. While both types of subdivisions appear throughout the KI literature (as can be seen below), we found only one article in which the two types are explicitly mentioned. This concerns Stein & Zwass' (1995) paper on organizational memory information systems (they call the two types of functions respectively 'mnemonic functions' and 'organizational effectiveness functions'). Below we will discuss how the two types of functions are discussed in the KI literature. In Chapters 3 and 4 we will see whether, in a KI system, one type of function is to be preferred over the other type of function in organizing KI systems.

Knowledge Functions

A first ground on which subsystems are discerned in the KI literature, is the function that subsystems have in relation to the knowledge they act upon. The simplest subdivision that we find here is one in two subsystems: a subsystem providing knowledge and a subsystem using knowledge. This distinction is one of the fundamental notions in economics, where resources are generated at one place, and, by means of a certain allocation principle, utilized at another place. An example where this division is made very explicit is that of technology transfer of Albino, Garavelli & Schiuma (1999). They distinguish between two systems of technology transfer: the information system and the interpretative system. The information system is responsible for the provision of information, and the interpretation system is responsible for the acquisition, communication, application, acceptance, and assimilation of knowledge in the organization. Similar subdivisions are made by, for example, Krikelas (1983), Taylor (1968), Boari & Lipparini (1999) and Spender (1996a).

Another subdivision in knowledge functions that is frequently applied in the current literature is based on Nonaka's (1994) typology of knowledge creation processes. Nonaka has inspired many scholars in the field of knowledge management. While Nonaka presents the processes of socialization, externalization, internalization, and combination as knowledge creation modes, Becerra-Fernandez & Sabherwal (2001) and. Zack (1999) use Nonaka's framework to identify four types of knowledge subsystems:

- From tacit to tacit: within-firm creation, sharing and integration
- From tacit to explicit: within-firm articulation and codification
- From explicit to tacit: reapplication and internalization
- From explicit to explicit: cross-firm transfer and imitation

A final decomposition that we will mention here is the decomposition by Stein & Zwass (1995), who distinguish between the following knowledge functions: knowledge acquisition, knowledge retention, knowledge maintenance, and knowledge search and retrieval. This type of decomposition is typical for many publications in the fields of organizational memory, knowledge management, and organizational memory information systems.

While these three decompositions into knowledge functions explicitly consider the knowledge functions as subsystems, other decompositions of KI into knowledge functions are numerous in the KI literature. However, they are not considered explicitly as subsystems by their authors. We will come back to this in Subsection 2.4.1, where we discuss patterns of KI activities. Also, they are listed in Appendix I.

System Functions

The second ground for distinguishing subsystems is the function that subsystems have in relation to the system of which they are part. A frequently observed subdivision is a distinction between a subsystem interacting with the environment, and a subsystem for the internal part of the system. We find this kind of systems in the literature on, for example, information seeking, boundary spanning, and environmental scanning. For example, referring explicitly to Katz & Kahn's work on systems theory (Katz & Kahn, 1966), Tushman (1977) considers organizations to consist of an internal subsystem that has no connection to the environment and a subsystem that interacts with the environment (the so-called boundary spanners). Another example is in the advancement that Zahra & George (2002) have made to Cohen & Levinthal's (1990) concept of absorptive capacity. Zahra & George distinguish between potential absorptive capacity (acquisition and assimilation of knowledge; representing the subsystem interacting with the environment) and realized absorptive capacity (transformation and exploitation of knowledge; representing the internal subsystem). A subdivision that is similar and used, for example, in literature on organizational learning, is the distinction between the exploration of new possibilities and the exploitation of old certainties (March, 1991; Schumpeter, 1934).

In the field of organizational memory information systems we find a subdivision that is more refined and distinguishes four subsystems. Based on the work of Quinn & Rohrbaugh (1983) and Parsons (1959), Stein & Zwass (1995) distinguish four functions contributing to four different aspects of organizational effectiveness. These functions also are distinguished by Wijnhoven (2003; 2005) in his work on operational knowledge management. The four functions are (as defined by Stein & Zwass):

1. Adaptive function: views effectiveness in terms of the ability of the organization to adapt to changes in its environment.
2. Goal attainment function: views effectiveness in terms of the ability of the organization to set goals and evaluate the degree of their fulfillment.
3. Integrative function: views effectiveness in terms of the organizational coordination and management of information across the organization.
4. Pattern maintenance function: views effectiveness in terms of the ability of the organization to maintain the cohesion and the morale of the workforce.

While there are some more decompositions of KI in system functions, they are not considered explicitly as subsystems by their authors. As for the knowledge functions, we will come back to this in Subsection 2.4.1. These functions are listed in Appendix II.

Control

Both the KI system and its subsystems are controlled by a controlling organ. This controlling organ (CO) sets goals for the KI (sub)system, evaluates the performance of the KI (sub)system, and tries to steer the KI (sub)system. In Subsection 1.3.1 (Contribution to Practice), we have deliberately excluded the CO for the KI system as a whole (meaning, at the level of analysis of this study) from our model, because this CO will be the targeted user of the outcomes of this study in practice. However, since a KI system is assumed to be recursive, the COs of the KI subsystems are part of the structure of the KI system. When we look in the KI literature for this third dimension of the internal structure of a KI system, we find three different approaches.

A first approach to positioning control in a KI system is positioning it in a separate system. When control is performed by such a separate system – a separate CO – this is called 'extrinsic control' (De Leeuw, 2000). We see it in some publications in the field of organizational learning, memory, and knowledge management. One of the most explicit examples is Wiig, De Hoog & Van der Spek (1997) who distinguish between two levels in knowledge management: a level of knowledge management activities (review, conceptualize, reflect, and act) and a level of knowledge operations (develop, distribute, combine, and consolidate). These two levels are virtually identical to the distinction between CO and TS. Another example that makes a similar distinction between the two systems is Wijnhoven (1995), who distinguishes between 1) organizational learning (the TS), and 2) monitoring information and control systems (the CO). In some literature on information seeking we find implicitly the same approach. In this literature, goals are considered as an input for information seeking to which feedback takes place (Wilson, 1999; Ellis & Haugan). Hence, it seems to be assumed there that the control function is performed by another system than the information seeking system or by the context of the information seeking system.

In the second approach, goal formulation, evaluation, and steering are considered as part of a sequence of KI activities. As such, control – implicitly or explicitly – is modeled as being performed by a KI system and not by a separate CO. This can be called 'intrinsic control' (De Leeuw, 2000). We see this, probably most explicitly, in the literature on organizational learning, where the results of actions are fed back to the goals that were set. Consequently, adaptation of actions takes place (single-loop learning) or adaptation of goals and actions (double-loop learning) (Argyris & Schön, 1978; Wijnhoven, 1995; Kim, 1993). We also see this in part of the literature on knowledge management (KM) where KM is seen as a process of KM activities. An example is Uit Beijerse (2000) who mentions 'determine the knowledge necessary' as the first phase of the KM process and 'knowledge evaluation' as the last phase. Another explicit example is Te'eni & Feldman (2001) who distinguish five cognitive processes for the location of text, starting with 'goal formulation' and ending with 'control'. Finally, also Choo (2002) distinguishes seven processes of information management of which 'needs' is the first and 'adaptive behavior' the last. Similar approaches are found in publications in each of the reviewed fields of literature. However, compared to the number of publications that do not include control in their sequence of KI activities, there are only few that do include them. An exception is the field of research methodology, where the research process usually starts with goals and follows a cycle in which evaluation and adaptation takes place. Examples of how goals are included there as a first phase are 'set the stage, plan and specify' (Flanagan, 1954), 'choose a problem' (Glaser & Strauss, 1967), and 'research objective' (Verschuren & Doorewaard, 1999). Evaluation and adaptation are usually presented as a feedback loop.

The third, and most common approach to positioning control in a KI system in the KI literature is by simply not including control. Within each of the reviewed fields, with the possible exception of research methodology, most publications that were found describe KI activities without referring to goals, evaluation, and adaptation. Rather than at this place invoking publications in which control is are not included, we refer to Appendix I, where we find numerous examples of publications that distinguish knowledge functions. As can be seen in that appendix, many of them do not at all refer to some form of control.

It is remarkable after the review of the KI literature from this third dimension of system structure, that virtually none of the publications we found considers control at more than one level of aggregation. A notable exception is the literature on organizational learning, where the interaction between individual learning and organizational learning is studied (e.g. Kim, 1993; Crossan, Lane, & White, 1999). While this literature does not explicitly distinguish between a CO and a TS, it explicates that control within a KI system is located at more than one level. For example, Kim (1993) distinguishes between the individual and organizational level, and Crossan, Lane, & White (1999) between the individual, group, and organizational level. We will explain this in more detail in Subsection 2.5.2, where we discuss the evolution of a KI system.

Consequences for KI

From this review of the KI literature that concerns the structure of a KI system, we can learn a number of things about KI that help us to develop a systemic KI model.

Concerning the levels of aggregation, it has become clear now that scholars have chosen different levels to analyze KI systems. We also can choose the level at which we want to model a KI system. For example, we can decide to model a KI system at the level of a group, an organization, or even a society. Considering that this study focuses on high-tech SMEs and not on societies, we will not model a KI system at the level of a society. Rather, we will choose a lower level of aggregation. Since most of the reviewed literature concerns these lower levels of aggregation, it seems that we can invoke much of this literature in developing a systemic KI model (see Chapter 4).

Concerning subsystems, we have seen that there are two distinct ways to decompose KI systems: based on knowledge functions and based on system functions. It is remarkable that, while the distinction between the two appears (explicitly, but more often implicitly) throughout the KI literature, knowledge functions – or more generally, resource functions – are virtually not mentioned in the literature on systems theory. Since subsystems are comprised of patterns of KI activities, we will further elaborate on this in Subsection 2.4.1. Considering that KI subsystems also are KI systems in themselves, we want to emphasize that what was said in the previous two subsections also applies to KI subsystems: they consist of knowledge, KI activities, actors, and technology, and have boundaries that are open and changing.

Concerning the control function in KI systems, we have seen that only few publications on KI make an explicit distinction between a controlling organ (CO) and a target system (TS). As long as the control function is somehow included, we think this is not a problem. After all, as argued before, the distinction between CO and TS is a conceptual distinction; in practice both functions might be performed by the same system and the same persons. However, we do believe it is problematic when the control function is not included at all. This is, as argued above, the case in a rather large share of the reviewed literature, which does not consider control, goals, evaluation, or adaptation at all. Since management is to a large extent associated with control, it is particularly remarkable that this also applies to much of the knowledge *management* literature. Another remarkable observation is that control is mostly assumed to be located at only one system level. The risk of such conceptualization of KI is that it can lead to a deterministic top-down view of KI. In line with the literature on organizational learning, we believe this is not a realistic view. In sum, we observe that, with exceptions, the control function is not very well developed in the current KI literature. Therefore, for developing the control function of a KI system in Chapter 4, we will deviate from the bulk of the reviewed literature and focus on those publications that are most in line with a systems perspective on KI (e.g. Wiig, De Hoog, & Van der Spek, 1997; Kim, 1993; Crossan, Lane, & White, 1999).

Finally, subsections 2.3.1, 2.3.2, and 2.3.3 have now provided the view on the structure of a KI system that emerges from the KI literature. The next section will complement this view with a review of what is said in the KI literature on the behavioral characteristics of KI.

2.4 System in the KI Literature: Behavioral Characteristics

The second type of characteristics of KI systems that we discuss are the behavioral characteristics. As presented in Subsection 1.2.2, these include the patterns of KI activities within a KI (sub)system (Subsection 2.4.1), and the interchange between KI (sub)systems (Subsection 2.4.2).

2.4.1 Differentiated and Patterned KI Activities

Subsection 2.3.3 has mentioned that two types of functional subsystems are distinguished in the current literature: subsystems based on knowledge functions and subsystems based on system functions. As repeated several times, in a KI system, the backbone of functions (and thus of subsystems) is patterns of activities. As a KI system has no physical structure, these patterns account for the stableness of the system. Before we move on to the particular patterns of KI activities as they appear in the current literature, we want to discuss what it actually means that a KI system consists of patterns of activities. To this end, we turn to the literature on (organizational) routines.

Routines are regular and predictable behavioral patterns of firms (Nelson & Winter, 1982: 118), or, as March & Simon define them: an organizational routine is "[…] a set of activities […] routinized to the extent that choice has been simplified by the development of a fixed response to defined stimuli" (March & Simon, 1958: 142). Routines are not those patterns of activities that are officially documented, for example, in manuals and instructions. Rather, routines are the actual patterns of activities in the organization (Feldman & Pentland, 2003). While these definitions of routines concern organizational routines, also individuals have routines: people have developed particular ways of working such that they do not have to decide about their actions every day again. While routines can be very effective and efficient in stable environments, in dynamic environments, however, there are few "defined stimuli". Therefore, in these environments, adaptation of the repertoire of these routines is thus crucial (Argyris & Schön, 1978; Levitt & March, 1988). It is however argued that many organizations do not have a wide repertoire of routines, because it requires such amounts of excess capacity to have them that it is hard for such organizations to survive (Hannan & Freeman, 1977). Consequently, as Hannan & Freeman argue, many organizations will only have a limited set of rather stable patterns of activities. When we copy this argument to KI systems, it is to be expected that these consist of a limited set of rather stable patterns of KI activities. Below, we will discuss what has been said about this in the current KI literature. As for the subsystems, we can distinguish two types of patterns of KI activities: according to knowledge functions, and according to system functions.

Knowledge Functions

In the current KI literature, numerous examples can be found of decompositions of KI into two or more knowledge functions (KFs). Often these KFs are instantiated as decompositions of a knowledge process into types of activities (cf. Alavi & Leidner, 2001). Because the number of different decompositions is huge, it is useful to somewhat organize them.

In Subsection 2.3.3 we have seen that from the perspective of KFs, it is rather common (in particularly in the information seeking literature) to distinguish between two types of systems: sources and recipients. When we consider the patterns of activities that relate to this subdivision of systems, we can observe that these have been central to the economic theories of the allocation of resources. These theories discern three patterns of activities: generation, allocation, and utilization of resources. Also in the reviewed KI literature, these are explicitly mentioned in the knowledge based view of the firm (Spender, 1996a) and some KM models (Choo, Detlor, & Turnbull, 2000). Moreover, a similar distinction can be found in Shannon and Weaver's (1949) communication theory (source, transmission, receiver). When we copy these three patterns of activities to the KI context, we arrive at the view that knowledge is generated at a source, allocated to a recipient, and utilized by the recipient. The economic models and their counterparts in the KI literature provide a bird's eye-view on systems consisting of multiple organizations; that is, they look at sources and recipients from an outside perspective. In this study, however, we are interested in the system that is integrating the knowledge; that is, the recipient of the knowledge. When we take the perspective of the integrating system, it is not the generation of knowledge that we are interested in, but its identification. Identification concerns those activities that connect a source to a recipient. The result is that the recipient can locate relevant external knowledge or an external source with relevant knowledge. Also, it is not the allocation of knowledge which interests us, but its acquisition by the KI system. Acquisition concerns those activities that establish a transfer of knowledge from source to recipient. Finally, since utilization already concerns the recipient, this third pattern can directly be copied to the KI context. Utilization, then, concerns those activities internal to the recipient that are performed in order to finally integrate the knowledge. Hence, this leaves us with three patterns of KI activities, or three KFs of the knowledge integrating system: knowledge identification, knowledge acquisition, and knowledge utilization (see also Kraaijenbrink, 2003; Kraaijenbrink, Faran, & Hauptman, 2005; Kraaijenbrink & Wijnhoven, 2006).

Above, it was mentioned that some KI publications have based their classification of activities on the economic theories of resource allocation. Additionally, the KI literature provides many other classifications of KI activities into KFs. Our review yielded 63 different classifications, which are summarized in Appendix I. Extending Alavi & Leidner's (2001) observation that the KM field mainly consists of decompositions of KM processes, we observe that most of the 63 classifications concern a sequence of KFs. Also, the fact that they are all 63 different, illustrates that there is no unified model of KFs available in the current literature. For example, the models differ in the number of KFs they discern, ranging from two (e.g. Hansen, 1999) to nine functions (e.g. Uit Beijerse, 2000). Moreover, they differ in the scope of KFs. For example, Bates (1979) concentrates on the input (i.e. information search), while Hedlund (1994) includes the input (i.e. assimilation), throughput (e.g. articulation, extension) and output (dissemination) of knowledge. Finally, they differ in the levels of aggregation they include. For example, while Wilson (1981) focuses on the individual level, Hedlund (1994) considers four levels of aggregation.

Despite of their differences, we can see that, throughout the several fields of literature, there is a lot of overlap between the classifications in that they concern similar activities. As we will show in the next pages, the activities mentioned in the literature can be categorized into the three knowledge functions described above. In this categorization we also include publications that concern single activities rather than classifications of activities.

Knowledge Identification

All activities from initiating a KI process up to and including locating specific external knowledge, are regarded as parts of the identification function. Dependent on who takes the initiative (source or recipient) we can distinguish three classes of knowledge identification. These three classes stem from the literature on environmental scanning. Aguilar (1967), Daft & Weick (1984), and Choo (2001) identify the level of intrusiveness of the seeker as a distinguishing aspect of information seeking behavior. In his distinction between solicited and unsolicited information, Aguilar also deemed this aspect distinguishing for the source. When the levels of intrusiveness of both source and recipient are seen as dichotomies, four types of identification can be distinguished. In our view, however, it can be either the source, the recipient, or neither that is intrusive. The fourth theoretically possible option (both source and recipient are intrusive) is not mentioned by Aguilar, Daft & Weick, or Choo. We further believe this is not relevant for our study since from the perspective of either the source or the recipient organization, depending on which is the most intrusive, this fourth option will be similar to one of the first two options in terms of KI activities. Moreover, we did not find any KI activities concerning the fourth option.

In total we found 51 knowledge identification activities in the KI literature. These are presented in Table 2.1. The references for these activities are given in Appendix I. Within Table 2.1, the three types of identification activities are indicated by 'R' (intrusive recipient), 'S' (intrusive source) and 'N (neither). When more than one initiator is given, this means that it can be the source *or* the recipient *or* neither that is most intrusive.

Table 2.1 Knowledge identification activities

KI activity	Initiator	KI activity	Initiator	KI activity	Initiator
Accessing	RS	Filtering	S	Noticing	N
Advertising	S	Finding	N	Presentation, directed	S
Alerting	S	Foraging	RS	Pushing	S
Analogical reasoning	R	Formulation	R	Querying	R
Assessment	R	Gap analysis	R	Recognition	R
Association	RN	Gathering	R	Retrieval	R
Attention, drawing	S	Identification of needs	R	Scanning	RS
Boundary spanning	R	Identification of source	R	Searching	R
Brainstorming	RS	Initiation	R	Seeking	R
Brokering	S	Inquiring	R	Selection	R
Browsing	R	Intelligence	RS	Sensemaking	R
Chaining	R	Interpretation	RS	Sourcing	R
Detection	RS	Linking	R	Spamming	S
Discovery	N	Localization	R	Surveying	R
Distinguishing	R	Mining	R	Tapping	RS
Encountering	S	Monitoring	R	Viewing	RS
Exploration	R	Navigating	R	Zapping	R

To stress the variety of knowledge identification activities we discuss some remarkable differences between the several activities. In addition to the difference between the activities caused by the intrusiveness of the source and the recipient there are a number of other differences between the identification activities mentioned in Table 2.1. Firstly, the activities differ in the degree knowledge is assumed to be created by the source or created by the recipient. For example, for 'retrieval' it is assumed that knowledge is created by the source and is only to be found by the recipient. On the other hand, for activities like 'brainstorming' and 'analogical reasoning', knowledge identification is much more a matter of generating knowledge together with a 'source'. Also, the activities differ in the degree to which knowledge identification and acquisition (or utilization) can be separated. While activities as 'formulation' and 'selection' can be considered as almost pure knowledge identification activities, activities as 'inquiring', 'gathering', and again 'brainstorming', include the acquisition of knowledge. This implies that not all KI activities can be exclusively attributed to one of the three KFs. We will come back to this after we also have discussed the knowledge acquisition and utilization activities. Secondly, the activities differ in the degree the source of knowledge is known in advance. In the case of, for example, 'sourcing' and 'tapping', the source of knowledge is known, while in the case of 'localization' and 'boundary spanning', the source of knowledge is not known in advance. Thirdly, they differ in the degree the knowledge need is specified in advance. For example, in the case of 'querying' and 'searching', the knowledge need is rather specified, while for 'browsing' and 'viewing' it is not exactly known in advance what one is looking for. This difference also implies a difference in the moment where the assessment of knowledge takes place. In the first case, most of the assessment of the knowledge that is needed occurs before some knowledge is found, while in the second case most of the assessment occurs after knowledge is found. Finally, the activities differ in the cardinality of the relationship between sources and recipients. For instance, in the case of 'navigating' and 'tapping' there is usually a specific source and recipient (1-to-1 relationship), while in the case of 'spamming' there is a 1-to-n relationship and in the case of viewing a n-to-1 relationship.

Knowledge Acquisition

In the acquisition function, knowledge is transferred from a source to a recipient. The conceptual difference between knowledge identification and acquisition is often ignored in the current literature. One of the exceptions is Hansen (1999), who explicitly distinguishes between knowledge search and knowledge transfer. Others sometimes include searching in the acquisition process (e.g. Gold, Malhotra, & Segars, 2001; Huber, 1991; Zahra & George, 2002) or even define it as the acquisition of information (Johnson, in Case, 2002). Conversely, Argote and Ingram have combined knowledge acquisition and utilization in their definition of knowledge transfer as "[...] the process through which one unit [...] is affected by the experience of another" (1999: 151). As argued above, based on economic theories of resource allocation, we have chosen to separate the three. Acquisition can take several forms, ranging from a document transfer to interactive cooperation. Based on the knowledge carrier, we can distinguish three types of knowledge acquisition. As suggested in Subsection 2.3.1, knowledge can reside in actors, activities, information technology, and non-information technology, and in combinations of these. This suggests that it can be acquired by moving one or more of these carriers across organizational borders. Table 2.2 provides a list of 50 knowledge acquisition activities mentioned in the current literature. In the table we refer to these types with 'H' (human actors), 'A' (activities), 'I' (information technologies) and 'N' (non-information technologies). Again, the references for the activities can be found in Appendix I.

Table 2.2 Knowledge acquisition activities

KI activity	Carrier	KI activity	Carrier	KI activity	Carrier
Abduction	HAI	Discussion	HI	Logistics	I
Absorption	HAIN	Dissemination	HAI	Mobility	H
Accumulation	I	Elicitation	HI	Moving	H
Acquisition	IN	Experimentation	HAIN	Negotiation	H
Action research	HA	Explicitation	I	Observation	HA
Adoption	N	Extraction	I	Outsourcing	N
Analysis	HAI	Grafting	H	Participation	HAN
Appropriation	I	Hiring	H	Prompting	HI
Asking	H	Imitation	AN	Protection	I
Assimilation	HAIN	Import	I	Replication	N
Brokering	H	Incorporation	I	Reporting	I
Collaboration	HA	Induction	HAI	Reverse engineering	N
Collection	I	Inferencing	HI	Sourcing	I
Communication	HI	Insourcing	N	Teaching	HAI
Cooperation	HA	Interaction	HA	Technology transfer	AIN
Course, following	HI	Interviewing	H	Transfer	HAIN
Deduction	I	Learning	HAIN		

As for knowledge identification, also knowledge acquisition activities differ in a number of ways. The first difference is the degree to which knowledge acquisition is considered an interactive process between source and recipient. For example, in the case of 'mobility' knowledge is transferred by moving the carrier (in this case an actor) from the source to the recipient without much interactivity. On the other hand, in the case of knowledge acquisition by 'cooperation', knowledge is acquired by much interaction between both parties. Of the activities mentioned in Table 2.2, most of them concern the more interactive type of knowledge acquisition. Secondly, knowledge acquisition activities differ in the intellectual efforts that are to be made by the recipient. For example, while 'logistics' and 'imitation' require relatively little intellectual efforts, 'inferencing' and 'extraction' require much more intellectual effort of the recipient. Thirdly, the activities differ in the direction of movement of a knowledge carrier. For example, in the case of 'action research' and 'participation', the knowledge carrier moves to the source (after which he will come back) while in the case of 'hiring' and 'insourcing' the knowledge carrier moves from the source to the recipient. Fourthly, the activities differ in the degree to which the source is informed about the knowledge acquisition. For example, in the case of 'collaboration' and 'teaching' the source is informed about the activity, while in the case of 'imitation' and 'reverse engineering' it might well be that the source is not informed about the knowledge acquisition. In the latter case, if the source would be informed about the knowledge acquisition, it might even have strong objections against it. Finally, the activities differ in the degree to which they include knowledge utilization elements. For example, knowledge 'transfer' as defined by Argote & Ingram (1999: 151), includes the use of knowledge by the recipient, while 'communication' does not include this use. We also saw this for knowledge identification activities.

Knowledge Utilization

Knowledge utilization is the aim of most knowledge transfer processes (Burnett, Brookes-Rooney, & Keogh, 2002), and requires additional activities to identification and acquisition, like the transformation of knowledge (Zahra & George, 2002). The knowledge utilization function consists of three types of internal knowledge activities that are frequently mentioned in knowledge management literature: logistics, transformation, and application. The first two are based on operations management and appear under headings such as sharing, storage, and dissemination (knowledge logistics) and knowledge creation, conversion, and combination (knowledge transformation) (Wijnhoven, 2003). The third is more constrained to the current knowledge management literature and involves the application of knowledge in organizational processes. As the reader might observe, knowledge logistics is rather similar to knowledge acquisition: both concern the transfer of knowledge. We distinguish them, however, because the perspective from which they are described in the literature is different. Knowledge acquisition concerns the transfer of knowledge from outside the KI system into the KI system. On the other hand, knowledge logistics concerns the transfer of knowledge within the KI system. Table 2.3 presents a list of 54 knowledge utilization activities that are mentioned in the current literature. The references for these activities are included in Appendix I. In Table 2.3, 'L' stands for logistics, 'T' for transformation, and 'A' for application.

Table 2.3 Knowledge utilization activities

KI activity	Type	KI activity	Type	KI activity	Type
Abstraction	T	Direction	LT	Processing	LT
Adaptation	T	Dispersion	L	Recombination	AT
Application	A	Dissemination	L	Recontextualizing	T
Appropriation	LT	Distribution	L	Recording	L
Articulation	T	Embedding	LT	Reflection	T
Assimilation	TA	Exploitation	A	Retaining	L
Codification	T	Extension	LT	Retention	LT
Combination	T	Externalization	T	Reuse	A
Communication	L	Formalization	T	Routinization	TA
Conservation	L	Implementation	A	Sharing	L
Consolidation	L	Indexing	LT	Socialization	TL
Construction	T	Institutionalizing	T	Storage	L
Conversion	T	Integration	T	Transformation	T
Creation	T	Intelligence	T	Translation	T
Decontextualizing	T	Internalization	T	Transmission	L
Developing	T	Interrelating	T	Unlearning	T
Dialogue	LT	Organization	TL	Use	A
Diffusion	L	Presentation	LT	Utilization	A

Also here we find a number of striking differences between the several activities. Firstly, considering the knowledge transformation activities, we can see that they concern different aspects of knowledge transformations. For example, 'externalization' and 'internalization' concern transformations of the tacitness of knowledge; 'decontextualizing' and 'recontextualizing' concern the context of the knowledge; and 'translation' concerns transforming the language in which the knowledge is expressed. Secondly, the knowledge application activities differ in the time perspective to which they refer. For example, while 'use' and 'application' refer to activities where the utilization follows the acquisition, 'reuse' and 'exploitation' refer to activities where the application takes place later. Another way of saying this is that in the first case knowledge is applied for the purposes it was acquired for, while in the second case it is applied for other purposes. Thirdly, knowledge logistics activities differ in the degree to which they concern purely logistic activities or also result in a transformation of the knowledge. For example, while 'storage' is used as a pure knowledge logistic activity, 'retention' includes the notion that knowledge is also transformed when it is stored (Weick, 1969: 125). Finally, the knowledge logistics activities differ in the direction in which knowledge is transferred within the organization. For example, 'direction' and 'processing' are instances of knowledge transfer from a KI controlling organ to a KI target system, while 'sharing' and 'diffusion' are much more instances of knowledge transfer between KI subsystems.

Discussion on KI Activities

When we consider all the KI activities that were mentioned above, there are some additional observations. Firstly, many of the KI activities listed under identification and acquisition also can be mapped to the utilization function. An example is the transfer of knowledge: this takes place both during acquisition of knowledge and during logistics of this knowledge in the organization. While the difference lies in the location of the concerned knowledge (external vs. internal to the recipient organization) the involved activities are similar. As argued above, since the literature differentiates between activities external and internal to the system, we have categorized activities internal to the system in the utilization function and activities external to the focal system in the other two functions.

A second remarkable observation is that in the utilization function the share of activities that originates from the knowledge management literature is substantially higher than in the other two functions. This corroborates the view that KM is mainly concerned with issues internal to organizations. As our review of knowledge identification and acquisition activities however shows, organizations also execute a large number of activities concerning external knowledge.

A third observation is that the various authors sometimes use different terms to refer to the same activity (synonyms) or use the same term for different activities (homonyms). We already gave examples of this in Subsection 1.3.2, where we compared Nonaka's (1994) and Hedlund's (1994) different terminology for the transformation of tacit knowledge into explicit knowledge and the different use of the term 'combination' by Nonaka (1994), Kogut & Zander (1992), and Wiig, De Hoog & Van der Spek (1997). Since our current objective is not the creation of a thesaurus or classification system of KI activities but to show the variety of KI activities discussed in the current literature, we leave this confusing terminology for what it is.

Fourthly, the reader may observe that each of the activities mentioned above is put very general. In other words, the activities in Tables 2.1 through 2.3 only contain verbs and no further specifications. This was done to make the list of KI activities not longer than it already is. When we would have included the specifications of the activities that are made in the literature, the list would probably contain over a thousand activities rather than the current 155. For example:

- We have not specified the actor that performs the activity. If we had done this, the 'learning' activity, for example, would have been further differentiated in individual learning, group learning, and organizational learning.
- We have not specified the object on which the activity is performed. If we had done this, the 'retrieval' activity, for example, would have been further differentiated in data retrieval, information retrieval, text retrieval, and knowledge retrieval.
- We have not specified the way the activities are performed. We have differentiated, for example, 'viewing' from 'searching'. If we would also have specified how viewing can be performed, this would have led to a further differentiation of viewing into 'undirected viewing' and 'conditioned viewing'.
- We have not specified the reason why the activities are performed. If we had done this, the 'intelligence' activity, for example, would have been further differentiated in business intelligence, competitive intelligence, and competitor intelligence.

Fifthly, as already remarked in the discussions on identification and acquisition, in some cases the activities can strictly be categorized in either identification, or acquisition, or utilization, but in other cases activities fit into two or even three categories. For example, 'elicitation' involves the identification of knowledge, the acquisition, but also the utilization in the sense that it transforms the knowledge from the source. This specifies rather than refutes our assumption that KI activities are specialized in terms of the functions they contribute to: some KI activities contribute exclusively to one function, while others contribute to multiple functions. Therefore, it seems appropriate to consider functions as aspects of KI activities rather than as rigid classes.

System Functions

Whereas KFs concern the effect of KI activities on the knowledge they operate on, system functions (SFs) concern the effect that the activities have on the system that performs them. In Subsection 2.3.3 we discussed a number of decompositions of KI systems into subsystems according to SFs. In the current subsection we investigate whether and how the current literature attributes KI activities to SFs.

When we review the KI literature for patterns of activities according to SFs, it is immediately apparent that the number of publications that provide such patterns is substantially lower than for the KFs. However, the number of classifications of KI activities into SFs is still considerable. As can be seen in Appendix II, we found 20 examples of such classifications. For the KFs, we were able to find a common denominator of most of the 63 classifications that were found in the literature in the form of the three KFs of knowledge identification, acquisition, and utilization. However, we have not been able to find a common denominator for the SFs.

When we look at the decompositions of KI into SFs that we found, we observe that there is variety amongst them. Firstly, some models formulate the functions in terms of outcomes, while others formulate them in terms of process. An example of the first is Santoro & Gopalakrishnan (2000), who distinguish four SFs of knowledge transfer activities: adaptability, sense-of-mission, involvement, and consistency. An example of the second is Wilson (1999), who distinguishes between four stages of problem solving in which information seeking should reduce uncertainty: problem identification, problem definition, problem resolution, and solution statement. Since processes are associated with outcomes, however, the difference of formulation is not so important. More important is that, as can be seen in these two examples, Wilson's classification does not correspond with Santoro & Gopalakrishnan's classification.

Another difference that we find is between the types of outcomes that are associated with KI activities. While, for example, March & Smith (1995) and Geurts & Roosendaal (2001) mainly concern intellectual products, Pahl & Beitz (1996) and Cooper (2001) concern physical products. This difference is highlighted by Allen (1977) in his seminal work on technology transfer. Allen provides a model of information processing in which he makes a distinction between physically encoded information and verbally encoded information.

There are, however, also similarities between the models. In terms of the number of functions, it is remarkable that more than half (12 out of 20) of the models that were found contain four functions. Although this may simply be traced back to scholars' preferences for two-by-two matrices, there also is some similarity amongst them. Three of them go back to the competing values model of Quinn & Rohrbaugh (1983) which is rather similar to Parsons four functions model (1959) (see Subsection 2.3.3). These models are Moorman (1995), Stein & Zwass (1995), and Geurts & Roosendaal (2001). Moreover, Tushman's (1977) model concerns one of the two dimensions of the competing values model (the internal/external dimension). Additionally, March (1991) combines the two dimensions into one: exploration vs. exploitation.

Concerning the patterning of activities in these models, the most explicit example is probably Moorman (1995). We discuss this example rather in detail because it is the only attempt that we found to empirically establish patterns of KI activities and relate them to

SFs. Moorman distinguishes four classes of KI activities (she calls them 'information processes'): information acquisition (5 activities), information transmission (6 activities), conceptual utilization (9 activities), and instrumental utilization (13 activities) (Moorman, 1995). Next, she uses the two dimensions of the competing values model of, amongst others, Quinn & Rohrbaugh (1983) as contingencies for the occurrence of the four classes of KI activities. She hypothesizes which classes are emphasized and de-emphasized by the two dimensions of the competing values model and by the four 'cultures' that lie at the intersection of these two dimensions. This is depicted in Figure 2.1.

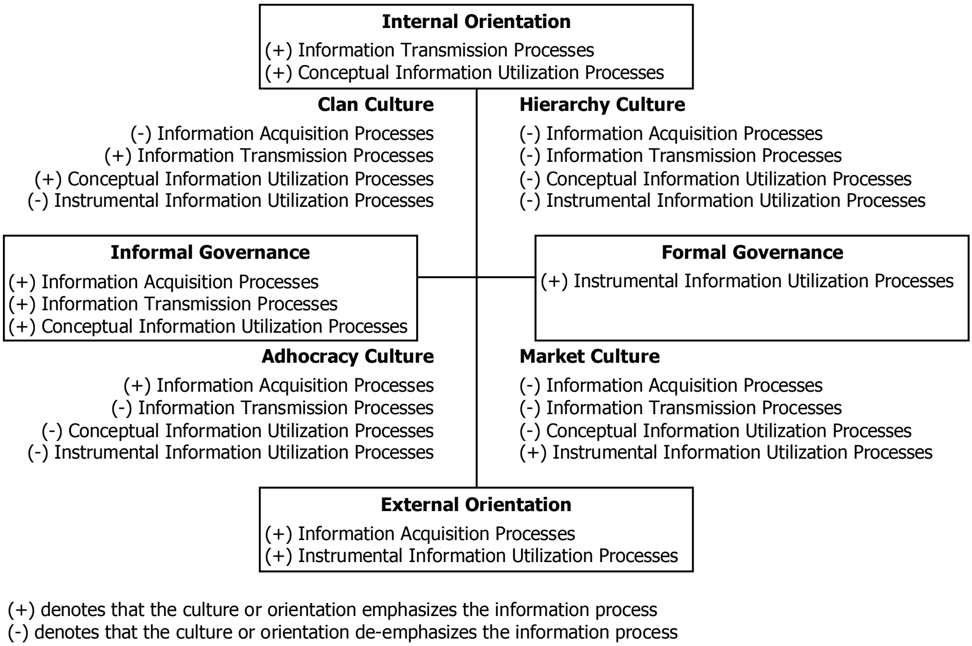


Figure 2.1 Information processes and competing values (adapted from Moorman, 1995).

Figure 2.1 proposes, for example, that a hierarchical culture de-emphasizes each of the four information processes and that external orientations emphasizes information acquisition processes and instrumental information utilization processes. While Moorman's work reflects one of the few attempts to relate patterns of KI activities to SFs the results of her study do not support the proposed relationships. With the explicit distinction between KI activities, KFs, and SFs we suggest a reason why Moorman failed to find support for her propositions: she tried to relate KFs to SFs, rather than KI activities to SFs. As was argued above, KI activities have at the same time KFs and SFs. Hence, it is not to be expected to find the relations Moorman was looking for.

Also adopting the competing values model, Stein & Zwass (1995) hypothesize for each of the four functions of their model (see Subsection 2.3.3) a number of activities to be performed by the concerning subsystem (they call these 'meta-requirements')

- *Adaptive function:* boundary spanning activities to recognize, capture, organize, and distribute knowledge about the environment to the appropriate organizational actors.
- *Goal attainment function:* helping the organizational actors frame and identify goal states, store goal states, formulate strategies for achieving goal states, evaluate progress in the direction of goal states, suggest alternatives based on the evaluations, update goal states based on new information, and store annotated histories.
- *Integrative function:* sharing and integration of memory over time and space.
- *Pattern maintenance function:* containing the work history of individuals, with emphasis on project descriptions, capabilities, skills, and aspirations; support the preservation of organizational protocols and the values implicit in them.

However, Stein & Zwass have not reported an attempt to find empirical support for their proposed patterns of activities.

Given these examples, the competing values model and the underlying four functions paradigm seem to have found their way into the KI literature. However, there are a number of other models that do not (explicitly) draw on it. An example is the typology of knowledge projects of Braganza, Edwarts, & Lambert (1999) who distinguish the following types:

- *Explore:* knowledge projects that test knowledge-enabled innovation that will lead to enhanced understanding of the idea and may lead to significant innovation. These projects are associated with radical product innovations.
- *Exploit:* knowledge projects that deliver significant innovation to gain advantage in the industry. These projects are associated with incremental product innovations.
- *Enhance:* knowledge projects that improve existing performance with the aim of maintaining competitiveness. These projects are associated with radical process innovations.
- *Expedite:* knowledge projects that improve efficiency and lead to avoiding cost increases in the longer term. These projects are associated with incremental process innovations.

Although we might be able to map this and some other models (e.g. Remus & Schub, 2003; Stenmark, 2001) to the competing value model their theoretical backgrounds are different. This means that there is no clear indication in the current KI literature on what SFs should be included in a systemic KI model.

Consequences for KI

As seen in this subsection, there is wealth of literature on KI activities. Our review as yielded 155 KI activities, 63 classifications according to KFs, and 20 classifications according to SFs. This shows that KFs have received more attention in the KI literature than SFs. This is somewhat surprising, since systems theory pays much more attention to SFs rather than to KFs (or more generally: resource functions). We also have seen that, although the number of classifications of KFs is three times as high as the number for SFs, the variety is less. Invoking economic theories of resource allocation, it was possible to reduce the number of KFs to three: knowledge identification, knowledge acquisition, and knowledge utilization. Concerning SFs, we were not able to do something similar. There was a particular lack of empirical support for these functions, implying that for the development of a systemic KI model, we will need to further investigate SFs.

From the results of this subsection we can learn a number of things about KI. Firstly, this subsection has made explicit that our conceptualization of KI is different – and particularly more comprehensive – than some existing conceptualizations. For example, with categorizing the application of knowledge as part of the utilization function of KI (see Appendix I), we take a rather different view than Alavi & Tiwana (2002) who consider KI to be a component of knowledge application. Also, we have categorized Grant's (1996) KI mechanisms of direction and routinization as part of knowledge utilization. These two examples show, that our definition of KI comprises much more than existing definitions do.

Secondly, the large number of different KI activities and classifications into KFs and SFs that were found in the literature, support our assumption that the literature on KI is fragmented rather than cumulative. Also, these numbers further illustrate how difficult it can be for practitioners to manage KI in their organizations.

Finally, we have seen that some activities cannot be exclusively attributed to one KF or to one SF. Rather, these activities can contribute to multiple functions at the same time. This suggests that, as argued above, the functions are to be seen as aspects of KI activities rather than as separate categories.

2.4.2 Interchange in a KI System

After having discussed the patterning of KI activities *within* a KI system, the second behavioral characteristic of a KI system is interchange *between* various (parts of) systems. We can distinguish between two types of interchanges: between a KI (sub)system and another KI (sub)system; and between a KI controlling organ and a KI target system. Since the latter concerns the control characteristics of a KI system, this type of interchange will be part of the discussions in Section 2.5. The current subsection will discuss how the KI literature deals with the first type of interchanges.

This type of interchange is particularly widely discussed as far as it concerns the interchange between a source and a recipient of knowledge. In the discussion of knowledge acquisition activities in Subsection 2.4.1, we have already seen that knowledge transfer can take place by means of the following carriers: actors, activities, information technologies, and non-information technologies, or combinations of these (see Table 2.2). Knowledge transfer respectively occurs by, for example, moving people, collaboration, moving documents, reverse engineering, or taking over another company. Since this part of the interchange between (sub)systems has already been discussed earlier, we will not elaborate anymore on it. However, to speak of an interchange, there also should be transferred something from the knowledge recipient to the knowledge source. Here we can distinguish two different cases. In the first case, knowledge is exchanged for other knowledge. This can be called interchange by barter. Examples of barter are contributing to a newsgroup because you get relevant knowledge in return (McLure Wasko & Faraj, 2000), filling out a questionnaire because you will receive the results back (Easton et al., 1997), and interorganizational knowledge creation, where two (or more) organizations together create new knowledge and as such both get knowledge in return for their activities (see e.g. Boari & Lipparini, 1999). Since this type of interchange can be seen as mutual knowledge acquisition, and since knowledge acquisition has been discussed before, we believe it is not necessary to further elaborate on it.

In the second case, knowledge is interchanged for something else, such as money. To follow the terminology used in social systems theory, we will use the term 'generalized media' to refer to this 'something else'. While the notion of generalized media will be further explained in Chapter 4, we define it, for the moment, as any means that is interchanged for knowledge from another KI (sub)system, or individual, with the exclusion of knowledge itself.

In the KI literature, this second type of interchange is addressed in research on the motivation of individuals and organizations to share their knowledge. This type of research draws on theories like Maslow's (1970) needs hierarchy, Blau's (1964) social exchange theory, and Herzberg's (1968) two-factor theory. Throughout the literature in the reviewed fields, we can find numerous of such motivations for sharing knowledge. We have categorized these motivations using Maslow's (1970) needs hierarchy[5]. While Maslow's needs hierarchy is originally not used for categorizing media for interchange, we believe it can be used for that purpose: actors share their knowledge in order to fulfill their needs. Hence, in effect, there is an interchange of knowledge for 'something' that fulfills their needs. Maslow suggests that people are motivated by five classes of needs: basic, safety, belongingness, esteem, and self-actualization needs. In his research on organizational memories, Wijnhoven (1999b) has translated the basic needs to gaining some form of financial income to be able to satisfy the basic needs. Additionally, Wijnhoven has defined safety needs as the guarantee of future income and employment guarantees. Using Maslow's needs hierarchy and Wijnhoven's adaptations, Table 2.4 categorizes some of the motivations for knowledge sharing that we found in the KI literature. Although Maslow's needs hierarchy only concerns individuals, we also have categorized motivations that are associated with organizations. An example is an organization providing information in advertisements to sell its products to customers.

As can be seen in Table 2.4, there is a variety of reasons why people share knowledge. The basic needs listed in the table all concern variations of the interchange of knowledge for money. However, we can find a number of differences between them. For example, they range from monthly payments, like salaries and subscriptions, to pay-per-use micro payments. These payments differ substantially in their amount and frequency. In particular the field of (online) information services this seems to be an important research topic. Also, while most of the payments listed concern direct payments (knowledge for money), the 'selling of products or services' concerns indirect payments: customers do not pay for the knowledge they receive, but for the additional products or services that they will buy.

Concerning the safety needs, we can see at least three different forms of interchange of knowledge for safety. The first two examples in Table 2.4 concern people sharing their knowledge because it is part of their job and they want to keep this job, for example, for financial or social security reasons. The second form that we find here is people sharing knowledge because somebody else exerts his power or authority. In this case, people share their knowledge because they fear for sanctions when they do not share it. While these two forms relate to individuals sharing their knowledge, the last form particularly refers to organizations sharing their knowledge. In both cases, organizations share there knowledge to survive the competition with their competitors.

[5] We only adopt the categories of Maslow's theory, not its assumptions that 'lower needs' need to be fulfilled before 'higher needs' can be fulfilled.

Table 2.4 Motivations for sharing knowledge

Motivator	Source	Field
Basic		
Money and salary	(Wijnhoven, 1999b)	Organizational memory
Revenue	(Wijnhoven & Kraaijenbrink, 2005)	Information services
	(Almeida, 1996)	Patenting
Financial rewards	(McLure Wasko & Faraj, 2000)	Knowledge sharing
Monetary incentives	(Forsgren, 1989)	Research data collection
Fees	(Warnken, 1991)	Information brokerage
Premiums, subscriptions, micro payments	(Clemons & Lang, 2003)	Information services
Selling products or services	(Nelson, 1970)	Advertising
	(Wijnhoven & Kraaijenbrink, 2005)	Information services
Safety		
Part of the job description	(Dodd, 1996)	Information brokerage
Future income and employment guarantees	(Wijnhoven, 1999b)	Organizational memory
Obligation	(McLure Wasko & Faraj, 2000)	Knowledge sharing
Power of others	(Blau, 1964)	Social exchange theory
Avoiding competence substitution	(McEvily, Das, & McCabe, 2000)	Knowledge sharing
Protecting the knowledge	(Almeida, 1996)	Patenting
Belongingness		
Affiliation	(Wijnhoven, 1999b)	Organizational memory
Network identity	(Dyer & Nobeoka, 2000)	Knowledge sharing
Access to a community	(McLure Wasko & Faraj, 2000)	Knowledge sharing
Reciprocity	(McLure Wasko & Faraj, 2000)	Knowledge sharing
	(Hendriks, 1999)	Knowledge sharing
Social utility	(Forsgren, 1989)	Research data collection
Moral obligation	(McLure Wasko & Faraj, 2005)	Knowledge sharing
Commitment	(McLure Wasko & Faraj, 2005)	Knowledge sharing
Responsibility	(Hendriks, 1999)	Knowledge sharing
Altruism/pro-social behavior	(McLure Wasko & Faraj, 2000)	Knowledge sharing
	(Forsgren, 1989)	Research data collection
	(Wijnhoven & Kraaijenbrink, 2005)	Information services
Advance a community	(McLure Wasko & Faraj, 2000)	Knowledge sharing
Enjoyment of helping others	(McLure Wasko & Faraj, 2005) (McLure Wasko & Faraj, 2000)	Knowledge sharing Knowledge sharing
Esteem		
Approval	(Blau, 1964)	Social exchange theory
Recognition and appreciation	(Hendriks, 1999)	Knowledge sharing
	(Spencer, 2000)	Science-industry interface
Respect	(Blau, 1964)	Social exchange theory
Showing expertise	(Almeida, 1996)	Patenting
Enhancement of professional reputation	(McLure Wasko & Faraj, 2005) (McLure Wasko & Faraj, 2000)	Knowledge sharing Knowledge sharing
Prestige	(Wijnhoven, 1999b)	Organizational memory
Status	(Blau, 1964)	Social exchange theory
	(McLure Wasko & Faraj, 2000)	Knowledge sharing
Feeling important	(Forsgren, 1989)	Research data collection
Obtaining power	(Wijnhoven, 1999b)	Organizational memory
	(Almeida, 1996)	Patenting
Self-actualization		
Operational autonomy	(Hendriks, 1999)	Knowledge sharing
Expect better task performance	(Loucopoulos & Karakostas, 1995)	Requirements engineering
Challenge of work	(Hendriks, 1999)	Knowledge sharing
Achievement	(Wijnhoven, 1999b)	Organizational memory
	(Hendriks, 1999)	Knowledge sharing
Promotional opportunities	(Hendriks, 1999)	Knowledge sharing
Competence	(Wijnhoven, 1999b)	Organizational memory

In the next category we find instances of interchange of knowledge for getting a sense of 'belongingness', that is, for being part of a community. There we find at least four different reasons why people share their knowledge. The first reason (related to 'affiliations' and 'network identify') concerns the individual need to belong to a particular group. In this case, people want to have a group of friends or peers to belong to. The second reason relates to 'access to a community', 'reciprocity', and 'social utility' and concerns the utility of sharing knowledge to a particular group. Having access to a particular community might bring the individual person utility, for example, by getting something in return for his contributions (reciprocity) or by getting something for the community (social utility). The third reason in this category concerns people's feeling that they cannot do otherwise than contribute. This relates to 'moral obligation', 'commitment', and 'responsibility'. As such, people are part of a particular community and feel it as their duty to also contribute to that community. Finally, the last three examples in this category concern the purely altruistic contributions of people. Here, people contribute their knowledge because they, for example, want to advance the community or because they want to help other people.

In the fourth category we find interchange of knowledge for esteem. Here, we can find at least three different reasons for sharing knowledge. The first reason (related to 'approval, recognition and appreciation, and respect) concerns people's need for approval by others. In this case, people might feel insecure and share their knowledge in order to be respected and appreciated by others. The second reason concerns people's need to show off their capabilities and knowledge. It is associated with 'showing expertise', 'reputation', 'prestige', 'status', and 'feeling important'. Finally there is the sharing of knowledge to obtain power. An example is sharing knowledge to build alliances.

In the last category, we find those motivations for knowledge sharing that concern self-actualization. We identify three reasons in this category. The first reason relates to 'operational autonomy' and 'expect better task performance' and concerns improvements people's current tasks. In this case, people share knowledge because it can improve their performance. This is the case, for example, when their knowledge is needed during requirements elicitation for a new software tool they might benefit from. The second reason in this category concerns the need of people to prove themselves. It is associated with 'achievement' and 'challenge of work'. In these cases people want to get the feeling that they achieved something. Finally, people share knowledge because it can help them in improving themselves. This reason is associated with 'competence' and 'promotional opportunities'. An example is people teaching the ropes of their jobs to their successors when they get an opportunity for promotion.

We started this subsection by mentioning the interchange between KI systems and the interchange between KI subsystems. So far, we have only spoken about the interchanges themselves. In this discussion we occasionally referred to interchange between organizations, but most of the time we referred to interchange between individuals. When we consider the five categories of motivations for knowledge sharing, their underlying theories attribute them to individuals. However, we believe that all can apply to both the individual level and the system level (either group or organizational level). For the basic and safety needs, as they are defined above, this is not hard to see: also groups and organizations strive for monetary rewards, need guarantees and safeguard themselves for threads from the environment. Concerning the ‘belongingness’ category, also groups and organizations strive to be part of a community and show altruistic behavior. Examples are, respectively, networks of organizations, and charities. Finally, concerning ‘esteem’ and ‘self-actualization’, we think it is rather obvious that groups and organizations also strive for things like prestige, power, and improvement. Although these examples do not sufficiently show that the five categories of motivations indeed apply to aggregations of individuals, we have found no reason to think differently. Hence, in this study we assume that they do apply.

Consequences for KI

In this subsection we have illustrated that, in the KI literature, there are two basic types of interchanges between KI (sub)systems. The first concerns the interchange of knowledge for knowledge; the second concerns the interchange of knowledge for generalized media. Considering that five types of knowledge and five categories of generalized media were distinguished, this subsection has demonstrated that interchange can take many different forms. Although probably not all forms can be applied easily in practice and in every situation, this shows that actors and KI (sub)systems have a potentially broad repertoire of means to obtain knowledge from other actors and KI (sub)systems.

2.5 System in the KI Literature: Control Characteristics

The third and final group of characteristics of a systemic KI model is the control characteristics. While the structural and behavioral characteristics respectively describe what a KI system *is* and what it *does*, control characteristics describe what a KI system *should* be and do. It concerns the goals that drive the KI system (Subsection 2.5.1) and the adaptations of the KI system that are needed to realize these goals (Subsection 2.5.2).

2.5.1 Goal-Directedness of a KI System

A first control characteristic of a KI system is that it is goal-directed. The goal-directedness of a system concerns the direction in which the activities are heading. Since KI systems consist of multiple levels and multiple subsystems (see Subsection 2.3.3) with their own goals, goal-directedness is not a homogeneous concept. Rather, it is shaped by actors and subsystems having several kinds of goals. Below we characterize two aspects of goals as they are discussed in the current KI literature: the type of goals and the way they are formulated.

Type of Goals

When reviewing the KI literature, we observe that the notion of a goal seems to be directly connected to the notion of a knowledge gap or a knowledge need. We have seen this already in Subsection 2.3.3, which provided examples of how goals are discussed in relation to the control function of a KI system. Following this literature, we assume here that KI activities are performed in order to fulfill some knowledge need. Knowledge needs can be diverse. In NPD they can vary, for example, from a specific need to know the behavior of a particular particle to a broad need to know the market for a new product. Also, they are different for every organization and every NPD project. However, when we abstract from these specific needs, it seems that we can reduce them to three types of goals: cognitive, affective, and situational goals (Choo, Detlor, & Turnbull, 2000; Menon & Varadarajan, 1992).

Cognitive goals concern the bridging of a cognitive gap. This type of goals is described as follows: "From time to time, movement is blocked by the perception of a cognitive gap – a situation in which people are unable to make sense of their experiences. To bridge this gap, individuals seek information to make new sense and use this information to help them continue on in their journey" (Choo, Detlor, & Turnbull, 2000: 4). Cognitive knowledge needs are characterized as 'sensemaking gaps' (Dervin, 1992; Weick, 1995), 'cognitive dissonance' (Festinger, 1962; Wilson, 1997) and 'knowledge gaps' (Allen, 1996). Examples are in the literature on sensemaking (Dervin, 1992; Weick, 1995), learning (Kolb, 1984), information foraging (Pirolli & Card, 1999) and data collection (Flanagan, 1954).

Affective goals concern the fulfillment of emotional needs. They are associated with uncertainty, anxiety, apprehension, confusion, frustration, lack of confidence, and stress (Kulthau, 1991; Kulthau, 1993; Wilson, 1997). Affective knowledge needs also are called 'emotional needs' (Wilson, 1994), 'psychological needs' (Wilson, 1981), and the need for 'gratifications' (Case, 2002). Examples of these types of goals are in the literature on information processing (reducing uncertainty, Weick, 1969; Daft & Lengel, 1984), and information seeking (for reducing uncertainty in problem solving (Wilson, 1999)).

Finally, goals do not only arise from individual – cognitive and affective – factors, but also from the situation (environment, context) in which actors operate (Wilson, 1981). An important part of this environment is the tasks that an actor performs (Case, 2002: 7). Situational goals originate in situations where actors cannot fulfill their tasks or perform their activities. MacMullin & Taylor (1984) suggest that situations can be characterized by a number of problem dimensions including the complexity, specificity, and risk magnitude of the task at hand. This third type of goal is adopted in a majority of the reviewed literature. Explicit examples are in the literature on knowledge reuse (Majchrzak, Cooper, & Neece, 2004; Markus, 2001), absorptive capacity (Cohen & Levinthal, 1990), crucial knowledge (Blaauw, 2005), knowledge intensive business processes (Remus & Schub, 2003), and information systems development (Scharl, Gebauer, & Bauer, 2001).

Although these three types of goals are analytically distinct, they are interrelated in practice (Wilson, 1981). This suggests that KI activities are driven by a mixture of these three goals and not by a single goal. It also suggests that the three types of needs are to be seen as aspects of concrete goals rather than as separate goals in themselves.

These three types of knowledge needs concern the *origin* of KI goals. Additionally, concerning goal-*directedness*, a further characteristic of KI goals that has received much attention in the KI literature is the degree to which KI is directed towards a particular goal. The field in which this is most explicitly considered is that of environmental scanning. Aguilar (1967) has distinguished four scanning modes (formal search, informal search, undirected viewing, conditioned viewing) of which the first two concern directed scanning and the latter two undirected scanning. More recently in this field, Daft & Weick (1984) and Choo (2002) have adopted Aguilar's typology. Also in the fields of information retrieval (retrieval vs. filtering, Belkin & Croft, 1992), information foraging (hunter vs. gatherer, Pirolli & Card, 1999), information seeking (searching vs. browsing, Xie, 2002; Marchionini, 1995), and research methodology (deductive vs. inductive, Dubin, 1978) this distinction is made.

A final characteristic of KI goals that has received considerable attention in the KI literature is their level of abstraction. This relates to the hierarchical level in a system at which the goals originate. At a higher system level, goals will be more abstract than at lower levels. We see this, for example, in organizations. When it concerns the organization as a whole, goals appear in the form of abstract mission statements and strategic objectives. When we move down to smaller parts of the organization, goals appear in the form of, for example, more concrete monthly targets and operating procedures. We find this difference in abstraction in the literature on organizational learning. For example, Wijnhoven (2001) distinguishes between four types of norms for organizational learning: policy norms, responsibilities, action norms, procedural norms. We also find this difference when we compare literature that concerns different system levels. For example, while Zack (1999) speaks of abstract knowledge strategies, Slone (2003) speaks of concrete search goals for Internet search.

Goal Formulation

Although goals may originate in one or combinations of the three types of needs mentioned above, this does not mean that goals automatically follow these needs. In systems, multiple actors interact with each other, each having their own goals. Goal formulation, then, is an interactive process between two or more actors. In the KI literature we find at least two types of interactive goal formulation: between system levels and between subsystems.

When we consider the role of individuals in collectives (like departments and organizations) there is a wide agreement in the literature that there is a mutual relationship between them. Researchers on collective thinking (Weick & Roberts, 1993), organizational decision-making (Simon, 1997), and organizational learning (Argyris & Schön, 1978; Fiol, 1994; Hedberg, 1981; Kim, 1993; March, 1991; Meeus, Oerlemans, & Hage, 2001) emphasize the mutual influence of individual and collective goals. An example is in the field of organizational learning. According to Kim (1993), individual and organizational learning goals are aligned by means of shared mental models. Another example is in the field of information processing where Corner, Kinicki, & Keat (1994) provide an integrated model of organizational and individual information processing.

Also concerning goal formulation between (sub)systems there is a wide agreement that it requires the alignment of goals of multiple actors. For example, there seems to be a common agreement now that knowledge needs cannot be defined by the knowledge seeker alone but rather are defined in interaction between knowledge source and knowledge seeker (Choo, Detlor, & Turnbull, 2000; Dervin, 1992). One of the most explicit references to this is Taylor's (1968) notion of 'question-negotiation'. According to Taylor, knowledge needs (he writes of information needs) go from a vicarious need, through a conscious and formalized need to a compromised need between knowledge source and seeker. Practically this suggests that actors go trough an iterative process in which they start with a vague notion of what they need, find something that seems to be relevant to fulfill that need, specify or change their need based on what they found, etc. This implies that not only the knowledge needs as described above guide the KI process, but also the knowledge that is available at sources. This dynamic goal formulation process between source and recipient also is explicitly recognized in, for example, the literature on information seeking (Wilson, 1981), information retrieval (Cole, 1998), knowledge reuse (Markus, 2001), environmental scanning (Aguilar, 1967), and absorptive capacity (Lane & Lubatkin, 1998).

Since goal formulation often involves multiple parties, there is the possibility of conflicting goals. In the current literature there are different views on the existence of these conflicts. At the one extreme end we find literature in which conflict is explicitly refused or is not mentioned. An example is the (early) literature on information processing, where it is assumed that managers gather information in order to reduce the uncertainty and equivocality for other members of the organization (Daft & Lengel, 1986). While this literature pays attention to differences between actors in the organization, conflicts are not considered. Another example is in the field of information seeking. Amongst others, Taylor (1968) and Wilson (1981) consider that the outcome of an information seeking process depends on the interaction between a source and a recipient. While both posses different knowledge, in the interaction they are supposed to strive for the same goal: fulfilling the information request. Other examples are in the field of knowledge reuse (Markus, 2001) where the source and the recipient of knowledge have different but non-conflicting goals and in organizational learning (Hedberg, 1981) where the individual and organizational actions and learning are supposed to mutually contribute.

At the other extreme end, we find literature in which conflicting interests abound. One example is Larsson et al. (1998) who present five learning strategies that the parties in an interorganizational relationship can choose from: collaboration, competition, accommodation, avoidance, and compromise. Another example is in the field of organizational memory information systems (OMISs). Stein & Zwass (1995) present four subsystems that each contribute to a particular organizational effectiveness function. Given that Stein & Zwass' model is based on the *competing* value model of Quinn & Rohrbaugh (1983), these four subsystems have to compete for, for example, organizational resources. This suggests that there is a potential for conflict between the four subsystems.

Consequences for KI

From the discussions in this subsection we can see that KI is not only reactive behavior that follows certain stimuli. Rather, it includes proactive activities driven by goals of individuals, subsystems, and systems. Of the many possible types of goals, this subsection has mentioned three general types: cognitive, affective, and situational goals. Assuming that these types of goals should be considered as aspects of particular goals, this suggests that a concrete goal of one actor is already a mixture of goals. This highlights that goal formulation does not follow automatically from a certain knowledge need, but requires additional efforts.

Additionally, the observation that goals reside at multiple actors in a system implies that a KI system is not a mechanistic or deterministic system where a controlling organ can fully determine its activities and outcomes. Rather, KI systems should be considered as organic systems where each actor affects KI activities and outcomes. This view on KI systems also suggests that the formulation of goals is an interactive process between actors with potentially conflicting interests.

2.5.2 KI System Evolution

The final system characteristic that we distinguish is the evolution of the KI system. KI systems are in a constant movement in order to adapt to internal and external pressures. As argued in Subsection 1.2.1, this adaptation of systems can be called learning. In the current subsection we will elaborate on the concept of learning, provide a typology of learning, and discuss how learning is assumed to take place when more then one system level is involved.

On Learning

Although only occasionally explicated in the KI literature, learning concerns the changes of a system that lead to a better functioning of the system. (De Leeuw, 2000). The learning process is perhaps best explained by David Kolb. Building on the work of Lewin, Dewey, and Piaget, Kolb (1976; 1984) presents learning as a four-stage cycle of concrete experience, reflective observation, abstract conceptualization and active experimentation (See Figure 2.2).

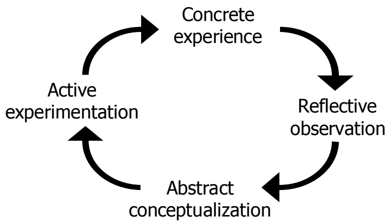


Figure 2.2 The experiential learning model (adapted from Kolb, 1976: 42)

From Kolb's experiential learning model we can observe at least three characteristics of learning. Firstly, the model shows that learning is a cyclical process. This cyclical nature of Kolb's model (and many other learning models, including Argyris & Schön, 1978; Boisot, 1998) shows many similarities with the evolutionary process of natural selection; consisting of variation, selection, and retention mechanisms. Zollo & Winter (2002) explicitly point at this similarity when they distinguish three learning mechanisms: experience accumulation (variation), knowledge articulation (selection), and knowledge codification (retention). The evolutionary model also has been adapted in the field of research methodology (e.g. Weick, 1989).

Secondly, the model shows that learning is an interplay between abstract conceptualization and concrete experience. This distinction has probably inspired other scholars to explicitly distinguish between two types or two aspects of learning. For example, Gioia & Manz (1985) distinguish between cognition and behavior; and Feldman & Pentland (2003) distinguish between ostensive and performative aspects of routines. Also, this seems to have inspired some scholars to focus on the cognitive part of learning (e.g. Huber, 1991; Liebeskind et al., 1996; Tsang, 2002), and others to focus on the behavioral part (e.g. Levitt & March, 1988; Zollo & Winter, 2002). While Kolb's model focuses on experiential learning, others have stressed that we also can learn from experiences of others or from models rather than from concrete experiences (Gioia & Manz, 1985). This is consistent with Kolb's model when we consider it as a model of a learning process of which not necessarily all activities take place by the same actor.

Thirdly, Kolb's model shows that learning is a process of adaptation, and not necessarily of accumulation. It seems that in part of the literature, learning has become a synonym for accumulating knowledge. We see this, for example, in the use of the term learning as sourcing (Liebeskind et al., 1996) or exchange (Meeus, Oerlemans, & Hage, 2001). Perhaps, this view on learning has led to the suggestion that unlearning is different from learning (Hedberg, 1981). However, when we follow Kolb and consider learning to be a process of adaptation, unlearning is included in this process. Hence, we believe no additional concept of unlearning is needed.

Types of Learning

The KI literature, and in particular the literature on organizational learning, distinguishes between three types of learning: single-loop learning, double-loop learning, and deutero learning. Argyris and Schön (1978) describe the difference between single- and double-loop learning as follows:

> *"When the error detected and corrected permits the organization to carry on its present policies or achieve its present objectives, then that error-and-correction process is single-loop learning. Single-loop learning is like a thermostat that learns when it is too hot or too cold and turns the heat on or off. The thermostat can perform this task because it can receive information (the temperature of the room) and take corrective action. Double-loop learning occurs when error is detected and corrected in ways that involve the modification of an organization's underlying norms, policies and objectives"* (Argyris & Schön, 1978: 2-3).

Wijnhoven (1995) characterizes the differences between single- and double-loop learning by associating them respectively with 'behavioral adaptation' and 'organizing'. Single-loop and double-loop learning are to be seen as two ends of a continuum rather than as two distinct types of learning (Argyris & Schön, 1978: 26). The concept of deutero learning is rather unambiguous (Visser, 2004). It is described as 'learning to learn' or 'learning how to carry out single-loop and double-loop learning'. As such it concerns changing the learning process itself. It creates awareness of the need for learning, implying that the other two types of learning will not occur unless some degree of deutero learning takes place. Deutero-learning defines the norms governing single- and double-loop learning (Wijnhoven, 2001). Also, it concerns the selection of ways of learning and the institutionalization of the learning process in the organization (Visser, 2004). When we relate the three types of learning to the three types of system characteristics described in this chapter, single-loop learning is associated with the adaptation of behavior, double-loop learning with the adaptation of structure, and deutero learning with the adaptation of control.

The notion of single-loop learning abounds in the KI literature that we reviewed. It appears, without exception, in each of the nine fields of literature, though not necessarily using the specific term. In some cases this concerns a feedback loop at the end of a series of activities (hence, constructing a cycle) (e.g. Carlile & Rebentisch, 2003; Choo, 2002; Corner, Kinicki, & Keats, 1994). In other cases it concerns a feedback loop after each activity (e.g. Daft & Weick, 1984). Also of double-loop learning we find examples in the KI literature. An example is information foraging, which "[...] is an approach to understanding how strategies and technologies for information seeking, gathering, and consumption are adapted to the flux of information in the environment" (Pirolli & Card, 1999: 643). Another example is in the field of KI, where the development and adaptation of routines is considered to be an effective mechanism for KI (Grant, 1996). In these examples, the adaptations that are made include the adaptations of the structure of a KI system – by adjusting the strategies and routines that are used. Concerning deutero learning, the KI literature is more silent. We found it only addressed in the specific literature on organizational learning (e.g. Wijnhoven, 1995; Argyris

& Schön, 1978; Visser, 2004). However, throughout the literature, we find numerous models of learning, of which we have presented some above. When we consider the reason why these models were developed, probably their main purpose is to make researchers and/or practitioners think differently about learning. As such, we can argue that their main purpose is to stimulate deutero learning of researchers and practitioners.

Learning between System Levels

The discussion above on learning concerned learning at one system level. However, as we have argued throughout this and the previous chapter, KI systems are hierarchical systems in which systems can be observed at multiple levels of aggregation. This suggests that learning can take place at various levels within a KI system and that there is some form of interaction between these levels of learning. This interaction has been extensively theorized in the field of organizational learning (Argyris & Schön, 1978; Fiol, 1994; Hedberg, 1981; Kim, 1993; March, 1991; Meeus, Oerlemans, & Hage, 2001). The insights of this field were combined by Kim (1993) into what he called an integrated model of organizational learning (see Figure 2.3). Kim tries to establish a link between individual learning and organizational learning. When we observe Kim's model, we recognize models of Kolb (1984), Hedberg (1981), and Argyris and Schön (1978). Kim stresses the importance of individual and shared mental models as a means to link learning at the individual and the organizational level.

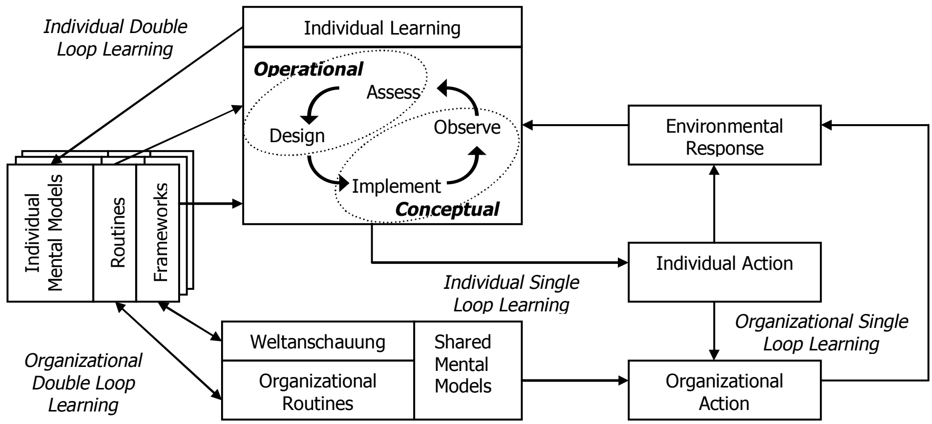


Figure 2.3 An integrated model of organizational learning (adapted from Kim, 1993: 44)

Where Kim distinguishes two levels of aggregation, Crossan, Lane & White (1999) consider organizational learning at the level of individuals, groups, and organizations. They suggest that the interaction between these levels consists of dynamic processes of assimilating new learning (feed forward) and exploiting what has already been learned (feedback). In Figure 2.4 we see how the three levels of learning are linked by the four activities of intuiting, interpreting, integrating, and institutionalizing.

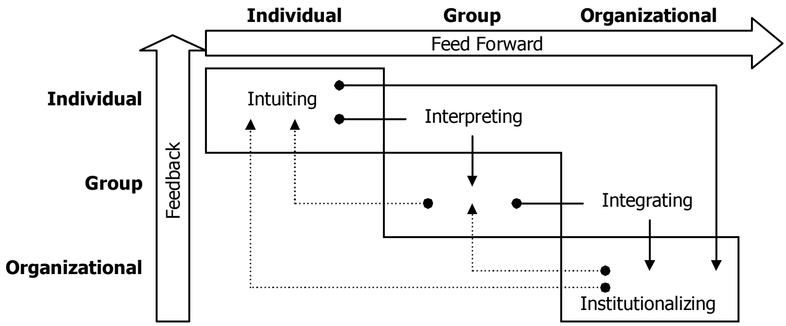


Figure 2.4 Organizational learning as a dynamic process (adapted from Crossan, Lane, & White, 1999)

Consequences for KI

This subsection has discussed the seventh and final characteristic of a KI system: system evolution. Together with the previous subsection, this subsection characterizes the control function of a KI system. From the current subsection we can observe that adaptations of KI can take place with respect to the structure, the behavior, and the control of a KI system. Also, we can observe that adaptations of a KI system involve adaptations of KI subsystems and individuals. It was argued that system evolution is discussed in the literature mainly in the field of organizational learning. We have seen that learning has both a cognitive and a behavioral aspect and that learning can take place from someone's own experiences, but also from the experiences of others and from models. This suggests that KI (sub)systems cannot only learn from their own experiences, but also from experiences of other KI (sub)systems and from models – like a systemic KI model.

What we find remarkable about the models presented in this subsection, is that neither Kolb's model, nor Kim's model, nor Crossan, Lane & White's model explicitly includes goals (unlike, for example, Wijnhoven (2001), who explicitly distinguishes norms for organizational learning, see Subsection 2.5.1). These models somewhat suggest that learning – and thus system adaptation – should be considered as a reactive process or as a goal in itself. Though we do not think this was what these authors intended, we hope that with explicitly including a subsection on goals we have provide a more active and goal-oriented picture of system evolution.

2.6 Assessment of the Literature

Sections 2.3 through 2.5 have provided an overview of systemic aspects covered in the current KI literature. In order to assess whether this literature forms a sufficient basis for developing a systemic KI model, we defined two criteria against which the literature should be evaluated:

1. There should be theoretical and empirical material on each of the seven characteristics;
2. This material should refer to an underlying systemic framework that can be used to develop a systemic KI model.

In this section we will assess to what extent the current literature meets these two criteria.

2.6.1 Criterion 1: Theoretical and Empirical Coverage

As we have presented a substantial amount of literature for each of the seven system characteristics, it is clear now that on each of the characteristic there is at least some theoretical or empirical material available in the current literature. When we scrutinize this literature in some more detail we can conclude the following for the seven characteristics.

Concerning the system elements there has been done extensive theoretical and empirical research on each of the elements of a KI system. Subsection 2.3.1 has presented theoretical and empirical findings on the five types of knowledge (in actors, activities, information technologies, non-information technologies, and in a system of these), on the actors in a KI system (internal, external, and control roles), and on the role of technologies in the system. Concerning the KI activities, Subsection 2.4.1 has presented numerous examples of theoretical and empirical contributions. Hence, we conclude that concerning the system elements, there is sufficient theoretical and empirical material available to develop a systemic KI model.

With respect to the boundaries of a KI system there also are many theoretical and empirical contributions available. As remarked in Subsection 2.3.2, most of these contributions depart from the basics of systems theory in that they automatically assume that the boundaries of a KI system are identical to the boundaries of the formal organization and that these boundaries are stable. However, there also were examples of publications that showed less rigid ways of considering system boundaries, for example, by considering a team, a project, or a network as the system and by focusing on changing system boundaries as a result of knowledge brokering activities. Therefore, we believe there is sufficient material available with respect to this second system characteristic.

The third structural characteristic was the internal structure of a KI system. In Subsection 2.3.3 we have seen theoretical and empirical contributions that concerned the hierarchical levels of a KI system and the KFs of a KI system. Also concerning the SFs, we have found some theoretical and empirical material. Finally, we have seen various theoretical and empirical contributions dealing with the control function in a KI system. Hence, we conclude that for this third structural characteristic – and for the three structural characteristics of a KI system – there is sufficient theoretical and empirical material available for developing a systemic KI model.

In Subsection 2.4.1 we have discussed the first behavioral characteristic of a KI system: patterns of KI activities. As remarked there, there are numerous theoretical and empirical contributions on KI activities. Also, concerning the patterning of these activities in KFs there is substantial theoretical and empirical work done. However, concerning the patterning of KI activities in SFs we have found some theory, but virtually no empirical results. Hence, it seems that for this characteristic of a systemic KI model, further empirical research is needed.

Concerning the other behavioral characteristic, interchanges between systems, Subsection 2.4.2 has presented examples of theoretical and empirical contributions. Concerning the variety of types of interchanges that appeared there, we believe that there is sufficient material available in the current literature with respect to this fifth characteristic of a KI system.

The sixth characteristic, goal-directedness of a KI system, was discussed in Subsection 2.5.1. Both with respect to the types of goals that direct a KI system and the way these goals are formulated in a KI system we have presented examples of theoretical and empirical contributions. Hence, we believe that concerning this first control characteristic of a KI system, there is sufficient material available in the current literature.

Finally, concerning the seventh characteristic of a KI system, system evolution, we have seen in Subsection 2.5.2 that there is substantial work done, in particular in the field of organizational learning. As discussed there, this field has extensively studied the learning process, the types of learning that occur and the interaction between learning at more than one system level. Hence, we conclude for this final characteristic that there is sufficient theoretical and empirical material available.

2.6.2 Criterion 2: Underlying Framework

While the first criterion concerned the amount and variety of the current KI literature, the second criterion concerns the convergence that this is necessary to develop one systemic KI model. As we can observe from the variety of the literature on each of the seven system characteristic, it may be clear now that there is no explicit or implicit reference to one underlying framework in the current literature. Hence, it seems that the current literature does not meet the second criterion. However, although the literature as a whole does not refer to one systemic framework, it could still be possible that there is already a systemic KI model available, but that it has not (yet) found its way into the KI literature. Hence, before we infer from this chapter that we should develop a systemic KI model, we should certify that we are not reinventing the wheel. To show that there is no systemic KI model available in the reviewed literature, we turn to the most complete model in terms of coverage of systemic characteristics that we found. This concerns Kim's (1993) 'integrated model of organizational learning' (See Subsection 2.5.2). This model has the following characteristics:

- *Elements of the system:* it includes actors (at least two), technologies (implicitly in the design activity of individual learning), KI activities (e.g. assess, observe, implement, and design), and knowledge (individual and shared mental models).
- *Boundaries of the system:* it considers the boundaries of the formal organization to be the boundaries of the system.
- *Structure of the system:* it distinguishes two levels: the individual and organizational level; it distinguishes no subsystems.
- *Differentiated and patterned activities:* it distinguishes no differentiated and patterned activities.
- *Interchange between systems:* it implicitly considers interchange between individuals, by means of shared mental models, and it considers interchange with the environment by means of organizational action and environmental response.
- *Goal-directedness:* it considers individual and organizational goals implicitly as part of the individual and organizational mental models.
- *System evolution:* it explicitly considers single-loop and double-loop learning and the interaction between learning at the individual and the organizational level.

Although Kim thus covers most characteristics of a systemic KI model, in the light of this study, there are a number of gaps. These gaps are perhaps not surprising, since Kim's focus is on organizational learning and our focus is on KI, of which learning can be seen as the evolutionary aspect.

The first gap is the attention that Kim pays to the link of the system with its environment. As Figure 2.3 in Subsection 2.5.2 has demonstrated, this link consists of individual observations, individual actions, and organizational actions. While, in his article, Kim invokes Daft & Weick's (1984) three stage model of organizations as interpretation systems (consisting of scanning, interpretation, and learning), we do not find it back in his integrated model. Hence, Kim provides little detail on the complexity and dynamics of this aspect of his model. Since, in this study our focus is on external knowledge, we need more detail on this aspect. Fortunately this is provided by many other studies.

The second gap concerns the general level of detail. Being a Sloan Management Review article, Kim has no opportunity to describe each part of his model in detail. The review of the literature in the previous three sections has provided already much more detail. What remains, though, is connecting this detail to a systemic KI model. This is done in Chapter 4.

The final and most important gap is that Kim does not distinguish functional subsystems and – connected to that – differentiated and patterned activities. Kim considers individuals but does not differentiate between them in terms of their roles and functions in the organization. Also the relation between activities and system functions is not explicated.

Because of the gaps in Kim's model, and the lack of an implicit or explicit reference of the current literature to an underlying framework, we conclude that the current KI literature does not meet the second criterion.

2.7 Discussion and Conclusion

This chapter started with the question as to what extent does the current KI literature provide sufficient theoretical and empirical material for developing a systemic KI model. We considered this material to be sufficient when there was theoretical and empirical material available on each of the seven characteristics; and when this material referred to an underlying systemic framework that could be used to develop a systemic KI model. In order to answer the research question, we performed a cross-disciplinary literature review in a broad range of fields, including information seeking, organizational learning, and research methodology. In the analysis of the collected literature we looked within each of the fields whether and how the system characteristics defined in Subsection 1.2.2 instantiated in that field.

As the body of this chapter has demonstrated, there are many similarities between the seemingly different reviewed fields. For example, the evolutionary nature of learning appeared in models of organizational learning and in models of research methodology. Although interesting, this similarity is not a new observation. For example, Kolb (1984) has mapped the stages of experiential learning onto scientific inquiry, decision making, and the creative process. On the other hand, this chapter has demonstrated that there also are many differences between the fields. An example is that system evolution is explicitly addressed in the literature on organizational learning (i.e. single- and double-loop learning), but is missing in other fields, including information seeking and knowledge management.

More importantly, it was demonstrated that the current KI literature fails to fully meet the two criteria that we formulated. Firstly, we found hardly anything on the empirical patterning of KI activities in terms of their SFs (see Subsection 2.4.1). Considering that patterns of activities are, in systems theory, assumed to be the backbone of a social system, this is rather surprising. There are some theoretical contributions on the patterning of activities according to SFs (e.g. Stein & Zwass, 1995), but no empirically based models: we found only one failed attempt to establish empirical patterns of KI activities (Moorman, 1995). When we look at the available models, the largest minority of them seems to draw on Parsons' social systems theory. Hence, we could decide to use Parsons' four functions for the patterning of KI activities. However, since empirical support is virtually lacking at this moment and other existing models might be more appropriate, this requires further empirical investigation. To this end, the next chapter describes an empirical study we conducted in order to empirically establish patterns of KI activities.

Secondly, we found no underlying framework in the current KI literature. Although there is sufficient material available on each of the other characteristics of a systemic KI model, it is impossible to integrate all this material into one systemic model. It also is undesirable because the model will be too complex to use. Hence, in the development of the KI model we need to be selective. As there is currently no underlying framework, we need further investigation in order to find such framework. Considering that the focus of this study and the core of a KI system are KI activities and their patterning into functions, the choice for this framework will depend on the outcomes of the empirical research on the patterning of KI activities in the next chapter.

CHAPTER 3: ANALYSIS PART II: EMPIRICAL STUDY

"The development of open systems theory requires the identification of patterns of social behavior [...]"

Katz & Kahn (1979:7)

"There is nothing like looking, if you want to find something. You certainly usually find something, if you look, but it is not always quite the something you were after."

Tolkien (1995)

3.1 Introduction

The first phase of this study consists of an analysis of material that is needed in order to design a systemic KI model. In Chapter 2, we have conducted the first part of this analysis, which concerned an analysis of the current literature. There, we have concluded that for developing a systemic KI model two things are still missing in the current literature: an empirical foundation for the patterning of KI activities, and a ground for selecting a systemic framework that can be used to develop the systemic KI model. This chapter tries to bridge these two gaps with an empirical study. As such, this chapter presents the second and final part of the analysis phase. As the empirical field on which we focus is that of NPD in high-tech SMEs, this empirical study is conducted in this particular field. Based on the results of this chapter and the previous chapter, in the next chapter we will move on to the next phase of this study: the design of the systemic KI model.

The main research question guiding the empirical study of the current chapter is: *To what extent does an additional empirical study on KI provide the empirical material that is missing in the current literature?* In answering this research question, we follow a two-stage approach consisting of in-depth semi-structured interviews and a large-scale self-administered questionnaire. The interviews are conducted as a preparation for the questionnaire to find out how practitioners in high-tech SMEs perceive KI and how they talk about it. The questionnaire is conducted to find patterns of KI activities, which in turn constitute a ground for choosing a systemic framework for the development of the systemic KI model. Both the interviews and the questionnaire were conducted in Germany, Israel, Netherlands, and Spain as part of a larger European study on KI (Knowledge Integration and Network eXpertise, KINX). We were responsible for the overall development, coordination, and analysis as well as for the data collection of the Dutch part of the study and the work package of which it was part.

The chapter is structured as follows. Section 3.2 discusses the method followed in the exploratory interviews and their outcomes. Consequently, Section 3.3 provides the operationalization of the quantitative study, followed by a description of the sampling and response in Section 3.4. The methods of analysis are discussed in Section 3.5. Section 3.6 presents the results of the quantitative study, where needed supported by the results of the interviews. While these results concern the empirical patterning of KI activities, Section 3.7 compares the results with the systemic KI models from the literature and as such concerns the selection of a systemic framework. Consequently, Section 3.8 further specifies the emerged patterning of KI activities by characterizing the responding SMEs. The final answer to the research question is given in the concluding Section 3.9. Previous versions of parts of this chapter are published elsewhere (Kraaijenbrink, 2005a; Kraaijenbrink, Groen, & Wijnhoven, 2005).

3.2 Exploratory Interviews

Kerlinger (1986) suggest three roles of interviews in research: as an exploratory device, as a main instrument, and as a supplement to a preceding study. Within this study, the preliminary interviews take the role of an exploratory device. Taking this exploratory role, the purpose of the preliminary interviews in this study is not data collection per se, but orientation in the field in order to create a good questionnaire. This purpose can be decomposed in the following purposes:

1. Get a rich picture of how KI instantiates in the context of NPD in high-tech SMEs. All the topics have been studied separately, but from previous studies it is hard to find out what it means to perform KI in this context.
2. Assess the relevance of a systemic KI model for practitioners. Within this study we have argued that a systemic KI model is relevant for practitioners, mostly by indirect evidence from slightly different fields. A second purpose of the interviews is to find out whether and how this relevance instantiates in the specific context of this study.
3. Learn the language in which SME practitioners speak about KI in their specific context. Scientific language and practitioners' language usually are very different (Kerlinger, 1986). Most of the concepts introduced in Chapter 2 are used for scientific purposes. For operationalizing the questionnaire we need to know the language of the practitioner.

This section discusses the research method (Subsection 3.2.1), the results (Subsection 3.2.2) and the implications of the preliminary interviews for the questionnaire development (Subsection 3.2.3).

3.2.1 Research Method for the Interviews

Interview Scheme

The interview scheme was developed by a group of experts from academia and practice (the KINX consortium, see Appendix III). Being conducted as part of the KINX project, the preliminary interviews covered a broad range of topics related to KI. For the majority of the interviews, the interview scheme as described in Appendix IV was followed. Considering the first purpose mentioned above, questions were asked about the following topics: 1) The way the companies conduct new product development (NPD), 2) the way they perform KI in this context; and 3) the methods, techniques, and tools they use during KI. Considering the second purpose, questions were asked about the problems that companies face during KI. By comparing the responses to these questions with the targeted contribution of a systemic KI model, we can assess the relevance of a systemic model for the respondents. Finally, considering the third purpose, we did not ask specific questions. By talking to the respondents and noting their reaction on interview questions we learned about the suitability of particular words and questions for the questionnaire.

Respondents

The targeted interviewees were R&D managers, marketing managers and, in case of small companies, directors of the company. Companies were selected by convenience sampling. To arrive at a sample in which a diverse set of companies is represented, companies were selected from different countries, sizes, years of foundation, and branches of industry. The final sample is presented in Table 3.1. The choice of the countries was based on the availability of interviewers within the KINX project.

Table 3.1 Sample for the preliminary interviews

Company	*Industry*	*# Empl*	*Year*	*Job*
Germany				
Aixtron	Semiconductor equipment	520	1983	Head engineering, Manager material research, Documentation manager
Cerobear	Ceramic rolling bearings	100	1989	Research engineer, Research engineer
HEAD Acoustics	Acoustic measurement	100	1986	Managing director, Production manager, R&D manager
Israel				
NUR	Macroprinters	370	1992	Chief operating officer, VP Marketing
Optibase	Digital video streaming	130	1990	VP marketing, VP R&D, Former VP marketing, VP international sales, Deputy VP R&D, IT director
Saifun	Semiconductors	105	1998	VP product development, Marketing manager, Director of operations
Netherlands				
Breumaf	Machine manufacturing	14	1984	Director
CSE	Optical electronics	2	1994	Director/engineer
Demcon	Mechatronics	35	1993	Director
Norma	Machine manufacturing	100	1954	Director
Osiris	Digital printing machines	4	2000	Technical director
Tevema	Precision instruments	19	1987	Director
Xsens	Sensors, electronics	6	2000	CEO
Spain				
Arteche	Electronics	450	1946	Engineer
COSIM	Machine manufacturing	170	1970	Engineering manager
IVM consultants	Engineering	25	1968	Marketing manager
Simes Senco	Metal manufacturing	107	1951	Administration
Zertan	Electronics	140	1979	Managing director
ZIV	Electronics and software	150	1983	Production manager

As can be seen in Table 3.1, the sample is probably not representative for the industries in the four countries. For example, the selected companies in the Netherlands are relatively small compared to the other countries, and the selected companies in Spain were rather old compared to the other countries. However, since our objective was not to get a representative sample, but to get a sample with a high variety, such that we would get a rich picture of KI in high-tech SMEs, the lack of representativeness is not a problem.

Data Collection and Analysis Procedures

The interviews were conducted in August through October 2002. The total number of interviewed people was 33, representing 19 companies. Interviews lasted between one and two-and-half hours and were conducted in the national language of the four countries. The total number of interviewers was 14. Each interviewer received precise instructions for the interview and an interview scheme (see Appendix IV). In Spain, a round table was organized with representatives of six companies.

After the interviews, the interviewers wrote a summary report of the interviews in their national language, again following the interview scheme, and sent it for a member check back to the SMEs (cf. Miles & Huberman, 1994). After some minor revisions, these summary reports were translated into English and collected by us for analysis.

The English summaries of the interviews were further compressed by coding the interviews into short sentences that summarized their content. Consequently, a cross-interview analysis was performed to find similarities and differences between interviews. Being conducted as part of the KINX project, the purpose of the interviews was broader than the three purposes mentioned above. However, the analysis in this study concentrates on the three purposes.

3.2.2 Results and Analysis

This subsection concisely presents the results of the preliminary interviews. For reasons of efficiency, no results of individual interviews are mentioned in this section. These are, however, mentioned in the summaries of the individual interviews (see Appendix I of Kraaijenbrink, Wijnhoven, & Groen, 2003)

Purpose 1: Description of KI

The interviews showed that each of the interviewed companies used knowledge from outside its company, in particular knowledge about customers and markets (e.g. 'market trends', 'news alerts', and 'feedback from consumer') and knowledge about technology (e.g. 'technologies and components', 'patents', 'new standards', and 'data sheets'). The third category that was mentioned in the literature (knowledge about organizational aspects of NPD, see Section 1.1) was not recognized by the respondents without further explanation. Also, they indicated that they hardly used external knowledge of this category. As far as they acquired this type of knowledge, the source pro-actively provided it to the SMEs. Examples are 'professional magazines discussing new quality norms' and 'branch organizations sending information on new subsidy regulations'.

The external sources reported as being important for the companies were customers (for customer and market related knowledge) and suppliers (for technological knowledge). Some of the interviewed high-tech SMEs were not end-producers; therefore they did not deliver to individual consumers. In these SMEs, knowledge about markets was not gathered by the SME, but by their customers. These customers were small and large companies which provided the SMEs with technological knowledge as well. This made, according to them, customers to very important sources of knowledge for the respondents. Other sources that were mentioned are, for market knowledge: market researches, the Internet, and trade shows and for technological knowledge: suppliers of machines, courses, journals, trade shows, patent databases, and the Internet. Consultancy firms were not mentioned as an important source, in particular not by some smaller firms because of the high costs of consulting them. Respondents tended not to do market researches as well for the same reason. About universities it was mentioned that their knowledge is usually not useful because it is too theoretical and too much communicated on paper rather than by personal interaction.

When we tried to picture a 'typical' KI process in the interviewed companies, we observed that an SME started with looking inside the firm for the necessary knowledge. As a next step it contacted its close network of suppliers, customers and other companies and as a third and last step sources outside this network were consulted. Some companies also had a board of advisors that was contacted after looking inside the firm. In addition to getting knowledge from these personal and informational sources, the interviewed SMEs conducted KI in other ways as well, like buying another company and analyzing products of competitors.

Interviewees reported that KI was conducted for two distinct reasons that can be seen as two ends of a dimension. The first was the use of the knowledge for a particular purpose (specific) and the second was learning (general). An example of the first was a focused Internet search followed by a close cooperation with the source of knowledge. An example of the second was following a course in management. Also many of the respondents stumbled upon relevant knowledge when they were not specifically looking for it.

From the interviews it became clear that KI was not organized as a separate or formalized process in the SMEs, but that they performed it as part of the NPD process (or any other business process, but the focus of this study was on the NPD process) without explicitly being aware of it. Consistent with this the respondents indicated that they hardly used or knew specific, methods, techniques, and tools (MTTs) for KI. With some exceptions, they did not explicitly make choices for certain methods, follow certain procedures or use specific tools. The MTTs that they did use for knowledge identification were search engines, catalogues and brainstorming. During knowledge acquisition they used checklists and contracts; and for knowledge utilization they used informal meetings, databases and intranets. In addition to these general MTTs, respondents made use of a few specific, content-dependent MTTs, like specific Internet portals. As an exception there were respondents that used data mining techniques and formalized procedures for getting customer knowledge. Also, it appeared from the interviews that the way the SMEs conducted KI and use certain MTTs has become an automatism for them. They used certain MTTs because they were used to them. As formulated above, the most important external sources of knowledge were part of a close network of companies around the SME. In contrast with this, MTTs that were used in the identification stage were used to find knowledge from sources outside this network.

Purpose 2: Assess the Relevance of a Systemic KI Model

Although the interviewed companies are quite satisfied with their KI success, they reported problems or needs for improvements as well. Some companies had clear-cut and urgent problems, like educating people for a particular purpose, or insufficient access to market information, but other companies did not come up with problems directly if we asked them about this. Only after asking more in depth and concrete questions they were able to mention certain problems. This seems to indicate that the respondents did have KI problems, but that problem awareness was low. Moreover, it appeared that problems were very much accepted by SMEs as being part of reality. Not being able to find needed knowledge within time was, for example, not seen as a problem, but just as a given situation that had to be dealt with.

From the three knowledge functions that were distinguished in Chapter 2, knowledge utilization seemed to be most difficult for the companies. A problem in knowledge identification that was mentioned was that the companies had to search too many sources and used too many unstructured ways to do this. Also, there was reported a lack of systematic process and a lack of overview. As a result, it cost too much time and resources to find the needed knowledge. In particular market knowledge seemed hard to find, which might be due to a lack of a direct relation with end consumers. In knowledge acquisition no problems were mentioned, except for contractual property rights related problems. It seemed that not the lack of knowledge (related to identification and acquisition) was the main problem, but the way to handle it in the organization to make it accessible and apply it effectively and efficiently (utilization). An example of this is a remark that not the shortage of knowledge is the problem, but a shortage of time to process it. The problems that were mentioned were most of an instrumental nature, that is, they were operational problems with performing KI. Some companies mentioned motivational problems (e.g. customers don not want to tell everything they know), but most of the problems are related to a lack of abilities and resources.

Concerning the need for a systemic model, it was particularly interesting that many of the interviewees somehow reported a lack of structure as a problem. Remarks that point in this direction are:

- 'There is no systematic collection of ideas, each employee collects ideas individually';
- 'The biggest danger is that you forget to take something into account from the start';
- 'It is difficult to achieve completeness, instruments that would support decision-making would be very interesting';
- 'The contact between the sales department and the engineering department is not structured';
- 'People are not aware of problems, they are only learning from mistakes';
- 'Utilization is very exhaustive and unstructured';
- 'There is an absence of methodologies';
- 'The internal process is the main deficiency';
- 'The problem is not the external knowledge but how to transform it into structured internal knowledge';
- 'There is no structure in the acquisition and utilization processes'; and
- 'The major challenge is how to organize, maintain and transfer the accumulated day-by-day knowledge in order to practically re-use it later and avoid re-inventing the wheel'.

These remarks were particularly made at the medium-sized (as opposed to small) firms. This call for more structure did explicitly not refer to a call for a formal or systematic method; this would harm firms' current flexibility. Rather it referred to a call for more overview of what they were doing. Hence, although far from conclusive, these results strengthen our argument that there is a need for a systemic KI model in practice.

Purpose 3: Learning Practitioners' Language

One of the things that we noticed during the interviews is that – like scientists – practitioners attach specific and different meanings to words like knowledge and information. For some practitioners they are synonymous, for others they mean something different, for example, at one SME it was remarked that 'people are struggling all the time with collection of information, not knowledge'. The problem with these concepts seemed to be that they are too abstract. When we talked about technological and market knowledge, it was a lot clearer to the respondents what we meant. However, as appeared from the difficulties that respondents had to talk about organizational knowledge, the term 'organizational knowledge' was too vague.

As mentioned under the results for Purpose 2, KI was perceived by the respondents as embedded in the NPD process and not as a separate process. Also, it was easier for the respondents to talk about NPD than to talk about KI. Examples of terms that respondents used were:

- Concerning knowledge identification: monitoring changes, looking, searching, visiting, and sending people to find information, benchmarking, market analysis, and business intelligence.
- Concerning knowledge acquisition: analyzing products and samples, outsourcing, hiring, getting documents, customer visits, ordering market reports, purchasing, and conference visits.
- Concerning knowledge utilization: internal transfer, enterprise intranet portal, spreading knowledge to employees, push the knowledge to the right people, organizing, maintaining and transferring day-by-day knowledge, practical reuse, problem-solving, and decision-making.

When we compare these examples to the terms used in the literature (see Chapter 2), there clearly are differences in that the terms mentioned above are closer to the NPD practice and more concrete. This implies for the development of the questionnaire that we should use terms of the NPD field rather than of the KM field and specific terms rather than abstract terms.

3.2.3 Conclusions on the Exploratory Interviews

From these interviews we tentatively conclude that high-tech manufacturing SMEs differ in the way they conduct NPD and KI, the MTTs they use, and the problems they have. Even different people within a single company answered differently to the questions. However, we observed that they are not so different as they believe themselves. Typically, their processes (both NPD and KI) are informal and based on habit rather than structured and formalized. Moreover they use few MTTs (only very common ones), don't deliberate upon advantages and disadvantages extensively, and look for satisfactory rather than optimal solutions because of time and money constraints. This is very much consistent with other research on SMEs (see, for example, Chapter 1).

Moreover, as we assumed in Chapter 1, KI is indeed to a large extent not approached systematically in practice. Also the fact that many interviewees perceived the lack of structure in their KI activities to be problematic, indicates a systemic KI model is relevant for practitioners. It appeared that such a model should not provide a rigid structure that should be followed. Rather it should provide overview of the KI process. This type of model is similar to the type of model that we intend to develop.

Finally, it appeared that the respondents are knowledgeable about the subject and hence that they are the right persons to address the questionnaire to. It also appeared that the language of the questionnaire should be 'down to earth', simple, and specific. Moreover, the questionnaire should, where possible, be formulated in NPD terminology. The interviews gave specific information about the type of terms that were used in practice.

Because of the exploratory and qualitative nature and the limited amount of the interviews, we are not able to draw strong conclusions about neither of the three purposes. However, the interviews have given us a rich picture of KI in NPD of high-tech SMEs, an overview of the type of problems that are faced during this process, and specific examples of the type of language that is used in practice regarding this subject. Hence, the interviews have met the three purposes that were set for it. The next section will explain how, based on the outcomes of the interviews, a questionnaire was developed.

3.3 Questionnaire Development

The objective for the questionnaire was finding empirical patterns of KI activities and, based on that, finding a basis for selecting a framework for the development of the systemic KI model. Based on the literature review, the interview scheme, and the outcomes of the interviews, a questionnaire was developed in the same expert group of researchers and practitioners that also had developed the interview scheme (see Appendix III). Those parts of the questionnaire that were only relevant for the KINX project are left out of consideration here. This study concentrates on those questions in which respondents were asked about the KI process. In total, this part represents approximately one fifth of the questionnaire.

3.3.1 First Version of the Questionnaire

A systemic model of KI suggests that KI activities are organized according to certain underlying functions they contribute to (knowledge functions or system functions, see Subsection 2.3.3). In order to empirically discover these underlying functions (or more generally, factors) it was decided to develop a questionnaire containing a collection of KI activities that could be analyzed for underlying factors.

The literature review of Chapter 2 presented a large number of KI activities. From the practicality perspective, it is, however, obvious that this number of KI activities cannot be included in a questionnaire. Practicality is concerned "[...] with a wide range of factors of economy, convenience, and interpretability" (Cooper & Schindler, 1998: 166). In particular in SMEs, practicality is important, because managers are usually overloaded with their daily activities and have little time to fill out questionnaires (cf. Scarborough & Zimmerer, 2000). Illustrative is a remark of one participant of our study that he at times received up to ten questionnaires a week, of which some were obligatory.

As mentioned above, we could only use one fifth of the questionnaire for the purpose of this study. When we consider that because of a lack of time to fill out questionnaires, the total length of the questionnaire should not exceed, for example, 30 minutes, this implies that filling out this part of the questionnaire should take a maximum of about six minutes. Hence, in order to create a questionnaire that could be filled out in a reasonable amount of time, we had to strictly limit the number of KI activities addressed in the questionnaire.

In our first attempt to make such a limitation we looked for existing scales and measurements instruments because of their proven validity and reliability. However, a search in the 800 reviewed publications and the ISWorld MIS Survey Instruments database[6] yielded no scales that concern KI activities. What we found, were, for example, scales on capabilities and outcomes (e.g. Lee, 2001; e.g. Szulanski, 1996), on IT support of knowledge management (Ruggles, 1998), on learning (Lyles & Salk, 1996), or on institutionalization of knowledge transfer activities (Santoro & Gopalakrishnan, 2000). Moreover, the few scales that we did find were rather lengthy lists of items, limiting the practicality of the questionnaire. An example is (Moorman, 1995) who provides a 33 item scale for market information processing. In sum, we found no validated scales that could be used for our exploratory study. The lack of measurement instruments for knowledge management activities was also observed by Gold, Malhotra & Segars (2001). Consequently, we proceeded with the development of a new questionnaire.

3.3.2 Pretest and Improvement of the Questionnaire

As an alternative approach, we developed a new questionnaire in close interaction with respondents. Based on the interview scheme and the outcomes of the interviews, a draft English questionnaire was developed and discussed in the expert panel of academics and practitioners (see Appendix III) Consequently, this draft questionnaire was tested in four subsequent pretesting rounds. Kerlinger (1986: 444 - 445) suggests seven criteria that can be used to evaluate interview questions.

1. The question should be related to the research problem and the research objectives.
2. The type of question (open vs. closed) should be appropriate.
3. The question should be clear and unambiguous.
4. The question should not be a directive question.
5. The question should not demand knowledge that the respondent does not have.
6. The question should not demand personal or delicate material that the respondent may resist.
7. The question should not be loaded with social desirability.

These questions were used as a guide for the pretesters. The exact instructions for the pretesters are given in Appendix V. The results of the four rounds are as follows:

Round 1

Language: English questionnaire.

Number of respondents: Germany: 2, Israel: 3, Netherlands: 3.

Setting: Individual interviews using a paper questionnaire.

Results: The questionnaire is too long; language is too complicated; technological knowledge and customer/market knowledge are recognized as separate categories, but organizational knowledge not.

Changes: Fewer questions, simpler language, omitting of category organizational knowledge.

[6] As for August 2002

Round 2:

Language: English questionnaire in Germany and Israel, Spanish version in Spain, Dutch version in the Netherlands (double-blind translations).
Number of respondents: Germany: 3, Israel: 2, Netherlands: 2, Spain 3.
Setting: Individual interviews using a paper questionnaire.
Results: The questionnaire has substantially improved but is still too long; some mistakes were made with filling out questions; instructions for filling out questions were not read.
Changes: Fewer and simpler questions.

Round 3:

Language: English questionnaire in Germany and Israel, Spanish version in Spain, Dutch version in the Netherlands (same version of the questionnaire as in Round 2).
Number of respondents: Expert team (see Appendix III).
Setting: Three hour round table meeting using the paper questionnaire.
Results: The questionnaire has substantially improved but is still somewhat too long.
Changes: Fewer and simpler questions; creation of a web-based version.

Round 4:

Language: German questionnaire in Germany, English questionnaire in Israel (the software that was used did not support Hebrew), Spanish version in Spain, Dutch version in the Netherlands.
Number of respondents: Germany: 5, Netherlands: 3, Israel: 2, Spain: 2.
Setting: Individual interviews with a web-based version of the questionnaire.
Results: Some minor errors.
Changes: Corrections of errors.

The result of these four pretest rounds is a short questionnaire that is included in Table 3.2. We believe that each of the questions mentioned in this table satisfies the seven criteria that were mentioned above.

3.3.3 Final Version of the Questionnaire

The final questionnaire contained single-item questions for 14 KI activities, which are mentioned in Table 3.2. For each of the KI activities respondents were asked about the frequency of executing that activity for technological as well as for customer/market knowledge. Although the use of multiple items is highly recommended in the literature, we had strong grounds to use single-item measures. From a theoretical perspective, KI activities lend themselves well to be measured by single items because they regard straightforward facts. There is no need to indirectly measure these variables, because they can be measured directly (cf. Wanous, Reichers, & Hudy, 1997). From a practical perspective, the pretests have shown that respondents resented being asked questions that seemed repetitious and that they better understood single items that directly measured the variables. Moreover, the use of single-items significantly reduced the length of the questionnaire, which is an important benefit in SME research, because of the usually low response rates.

A single balanced 5-point Likert-type scale was used, with only the two extremes given to the respondent. We used the extremes ‘never’ and ‘always’ because the pretests showed that extremes that were less strong (e.g. ‘hardly’ and ‘very often’) did not sufficiently cover the range of likely responses. A more fine-grained scale than the 5-point scale was indicated as being too subtle. In addition to the questions on the KI activities the questionnaire contained also a number of control variables to get a profile of the respondents (and additional questions relevant for the KINX project, but not for this study).

As a basis for selecting KI activities we used the three KFs that were mentioned in Chapter 2 (identification, acquisition, and utilization of external knowledge). We refer to this model as the 3KF model. Within the KFs we selected as few as possible activities that still reflected the variety of activities for that KF. We chose to focus on variety since variety is important for solid theory development (Weick, 1989).

As discussed in Subsection 2.4.1, there is much variety in the identification of external knowledge dependent on the level of intrusiveness of the source and the recipient. Questions 1 through 3 (Table 3.2) respectively represent activities in which neither the source nor the recipient is intrusive, in which the recipient is intrusive, and in which the source is intrusive.

Concerning knowledge acquisition, there is much variety in KI activities by the carrier of the knowledge. Questions 4 through 6, respectively, represent activities in which the carrier is information technology, non-information technology and actors. Since knowledge acquisition is often not a one-way process as reflected in these three activities, three more activities were added that take into account the interactive nature of knowledge acquisition (Questions 7 through 9). Instead of ‘following a course’, we initially included ‘talking with the source’ as a means of acquisition. However, this was seen as so obvious that it annoyed some respondents. Therefore it was changed into ‘following a course’.

As also discussed in Subsection 2.4.1, knowledge utilization activities can be categorized into three different groups: application, logistics and transformation. Questions 10 and 11 represent two types of knowledge application; questions 12 and 13 represent two types of knowledge logistics. For question 14 we initially had included two questions representing two types of transformation: ‘direction’ and ‘routinization’ (Grant, 1996). The difference between direction and routinization and between direction and diffusion in the utilization stage was however not clear to the respondents. Also after an explanation of the difference, they indicated that this difference was too subtle. Consequently, direction and routinization were combined in one activity: internalization. The final English questionnaire is presented below in Table 3.2. All questions in this table were asked both for technological knowledge, and for customer/market knowledge.

Table 3.2 Final English questionnaire

Nr.	Name	Activity	**Question** (5-point Likert, ranging from never (1) to always (5)
There are several ways to find external knowledge. How often do the following ways occur in your company?			
1	DISCOVER	Discovery	We come across knowledge without really looking for it
2	SEARCH	Intentional search	We intentionally search for knowledge
3	PRESENT	Unasked presentation	Another organization presents knowledge unasked
There are many ways to obtain knowledge if its source is known. How often do the following ways occur in your company?			
4	WRITTEN	Written documents	We receive documents or files from a source
5	PHYSICAL	Physical objects	We analyze products from a source
6	PEOPLE	People transfer	We hire or employ persons from a source
7	COURSE	Following a course	We attend a course given by a source
8	COOPERAT	Cooperation	We develop a product together with a source
9	OUTSOURC	Outsourcing	We outsource a problem to a source
Obtained knowledge can be used in several ways. How often do the following ways occur in your company?			
10	APPLICAT	Application	We use it for the goal we acquired it for
11	EXPLOIT	Exploitation	We use it for other goals than we acquired it for
12	STORAGE	Storage	We store it for potential later use
13	DIFFUSIO	Diffusion	We disseminate it to everybody concerned
14	INTERNAL	Internalization	We make sure that we have similar knowledge internally available next time

In order to characterize the responding SMEs, the following control variables were included in the study.

1. COUNTRY: Germany, Israel, Netherlands, and Spain.
2. SIZE: Number of employees.
3. AGE: Year of foundation.
4. INDUSTRY: ISIC Rev 3. Code 24, 29-35 (See Table 3.3 below).
5. PERCNEW: Percentage of sales generated by new and improved products, six categories: 0%, 1-20 %, 21-40 %, 41-60 %, 61-80 %, and 81-100 %.
6. PRODUCT: Characterization of the main product: machinery/equipment, components, consumer products, materials, software.
7. SCALE: Scale of the production process: single unit, small series, large series, or mass production.
8. PERCR_D: Percentage of employees working in R&D; measured by the ratio of number of people working in R&D / total number of employees.
9. PERCACA: Percentage of employees with an academic degree, measured by the ratio of number of people with an academic degree / total number of employees.

Control variables 1 through 4 were not included in the questionnaire but were collected from the sample databases.

3.4 Sampling and Response

3.4.1 Sampling

In order to create a sample of high-tech manufacturing SMEs we have to specify what we mean by 'high-tech manufacturing' and by 'SME'. While we have touched upon this in Section 1.1, we need a more precise definition at this point.

For the definition of 'high-tech manufacturing' companies we adopt the official International Standard Industrial Classification (ISIC) of high-tech and low-tech industries (see Table 3.3). This study includes firms of both high-technology and medium-high-technology industries (throughout this thesis we refer to both as 'high-tech SMEs').

Table 3.3 Industry classification (source: OECD, 2001)

Included in this study		Excluded from this study	
Code	*High technology industries*	*Code*	*Medium-low-technology industries*
353	Aircraft and spacecraft	23	Coke, refined petroleum prod., nuclear fuel
2423	Pharmaceuticals	25	Rubber and plastic products
30	Office, accounting and computing machinery	26	Other non-metallic mineral products
32	Radio, television and communications equipm.	351	Building and repairing of ships and boats
33	Medical, precision and optical instruments	27	Basic metals
		28	Metal products, excl machinery & equipm.
	Medium-high-technology industries		*Low-technology industries*
31	Electrical machinery and apparatus	36-37	Manufacturing and recycling
34	Motor vehicles, trailers and semi-trailers	20-22	Wood, pulp, paper, printing & publishing
24 excl 2423	Chemicals excluding pharmaceuticals	15-16	Food products, beverages and tobacco
352+359	Railroad equipment and transport equipment	17-19	Textiles, textile products, leather & footwear
29	Machinery and equipment		

The borderline between SMEs and Large Sized Enterprises (LSEs) is arbitrary. In the literature we find many different rationales for drawing this line, including turnover, working capital, and number of employees. For choosing a rationale for sampling in this study it is important that it is practical; that is, that it can be used in each of the four countries in which the questionnaire was to be conducted. In this study, we have chosen to take the number of employees as a rationale because we expected that most databases will register it. Financial indicators are more sensitive and thus less likely to be registered. Concerning the number of employees, the cutting off points that are used to distinguish SMEs from LSEs vary from 100 to 500 employees (Nooteboom, 1989). The formal European definition of SMEs includes only companies that have fewer than 250 employees (European Commission, 1996). There are however indicators that companies with up to 500 employees still have many 'SME characteristics': ownership and management in the same hands; often family-owned; lack of a dominant position in the market; and lack of solid management structures (European Commission, 1996). Since this research concerns high-tech manufacturing SMEs, the boundary of 250 employees is likely to be on the lower side. Namely, while the average company in Europe has 6 employees, for manufacturing firms, this number is 14 (European Commission, 2002c). Moreover, for those branches that are defined as high-tech manufacturing by the OECD (2001) the average number of employees is 20. This implies that the average size of the companies this research focuses on is more than three times as high as the overall European average. Therefore, we include companies with up to 500 employees in our study.

A major challenge was the selection of high-quality address databases for the questionnaire. Since we are not aware of any database that covers the four countries, we had to select four different databases that allowed selection on similar criteria. Because of their high-quality reputation and similarity, the following databases were selected: Hoppenstedt (Germany), D&A HiTech Information Ltd. (Israel), National Chamber of Commerce (Netherlands), and AXESOR (Spain). From these databases, we selected a stratified random sample of 1722 high-tech manufacturing SMEs. The sample was stratified over country (Germany, Israel, Netherlands, and Spain), size (2-9, 10-49, 50-99, and 100-499 employees), and industry (industries 24 and 29-35 from the International Standard Industrial Classification). These companies were contacted by phone, were asked to identify a key informant, and received a personal (web based or paper-and-pencil based) questionnaire with an accompanying letter. Although the validity of single-informants research has been debated, Campbell (1955) concludes that this type of sampling can produce results that are valid and generalizable. Also, we agree with Kumar, Stern, & Anderson (1993) who state that informants are not selected to be representative of the members of a studied organization, but because they are supposedly knowledgeable and willing to communicate about the issue being researched. Since smaller companies are less likely to have such informants than large companies (Mitchell, 1994), we let companies decide themselves who was the most appropriate person to respond. During the telephone calls we asked respondents whether they were indeed the right person in the company to answer the questionnaire. We had expected that this self-selection mechanism would lead to a strong overrepresentation of technology-oriented respondents compared to market-oriented respondents. This expectation was based on an assumption that NPD in high-tech SMEs would be associated with research and development rather than with marketing. While our expectation was partly right, Table 3.4 indicates that also a substantial number of market-oriented persons responded. When the selected respondents did not respond within the indicated period (two weeks) they were reminded up to two times, which is reported to be the optimal number of reminders (Babby, 1995).

3.4.2 Response

From the 1722 SMEs that were initially selected, 416 were excluded from the sample for several reasons, including wrong addresses and wrongly classified as high-tech SME. A breakdown of reasons for non-response and the response rates in the four countries is included in Table 3.4. A total of 317 SMEs responded, leading to a response rate of 24.3 %, which is considerably high for a randomized sample of SMEs (Huang, Soutar, & Brown, 2002; Raymond, Julien, & Ramangalahy, 2001).

Table 3.4 Breakdown of response

	Germany	Israel	Netherlands	Spain	Total
A. # of responses companies total	68	98	110	41	317
B. Final total sample size	400	632	400	290	1722
C. Response rate (A/B)	*17.00%*	*15.51%*	*27.50%*	*14.14%*	*18.41%*
D. Unable to contact	14	138	36	52	240
E. Remaining sample (B-D)	386	494	364	238	1482
F. Response rate (A/E)	*17.62%*	*19.84%*	*30.22%*	*17.23%*	*21.39%*
G. Not an SME anymore	3	21	19	2	45
H. Remaining sample (E-G)	383	473	345	236	1437
I. Response rate (A/H)	*17.75%*	*20.72%*	*31.88%*	*17.37%*	*22.06%*
J. No manufacturing	28	4	10	0	42
K. Remaining sample (H-J)	355	469	335	236	1395
L. Response rate (A/K)	*19.15%*	*20.90%*	*32.84%*	*17.37%*	*22.72%*
M. No product development	42	0	47	0	89
N. Effective basic sample (K-M)	313	469	288	236	1306
O. Effective response rate (A/N)	***21.73%***	***20.90%***	***38.19%***	***17.37%***	***24.27%***
P. Technical problems web survey	0	4	6	0	10
Q. Never answer questionnaires	19	1	16	0	36
R. No time / not interested	186	14	77	195	472
S. Other	0	2	0	0	2
T. Unknown	43	350	84	0	477

Since we followed the same procedures in each country, the high response rate in the Netherlands was surprising. One possible explanation is that Dutch governments pay relatively much attention in their policies to the acquisition and use of external knowledge by SMEs, leading to an increased interest in KI. During the interviews, the interest of NPD managers in our study indeed seemed higher in the Netherlands than in the other countries.

The profile of the responding companies and individuals is given in Table 3.5. A comparison (t-test and Mann-Whitney test) of respondents with non-respondents showed no significant differences on industry (2-tailed significance for t-test was .904 and for Mann-Whitney was .516). However, regarding company size the difference were significant (both tests showed a significance of .000). Companies with 10-49 employees were relatively underrepresented in the response set, while companies with over 100 employees were relatively overrepresented. Also concerning company age, differences were significant (.083, respectively .002 for t-test and Mann-Whitney test). Younger companies were relatively underrepresented, while older companies were overrepresented. We had no theoretical reasons to assume that these over- and under-representations were relevant for the outcomes of the study. Moreover, a comparison (t-test) of early and late respondents on all variables in this study showed no significant differences (at $p<0.05$). Thus, substantial non-response bias seems unlikely (Armstrong & Overton, 1977).

Table 3.5 Profile of respondents and their companies

Industry	%	Year of foundation	%
24 Chemicals & chemical products	10.7	Before 1965	13.1
29 Machinery & equipment	28.4	1966-1980	13.1
30 Office machinery & computers	11.7	1981-1990	18.0
31 Electrical machinery & apparatus	4.1	1991-1995	14.6
32 Radio, TV and communication equipment	19.9	1996-1998	15.5
33 Medical, precision & optical instruments	12.6	1999-2001	16.2
34 Motor vehicles, trailers & semi-trailers	5.0	Missing	9.5
35 Other transport equipment	3.2	(after 2001 excluded)	
Missing	4.4		

# of employees	Total	On R&D	Position of respondent	%
2-9	14.3 %	58.5 %	Director/general manager	29.9
10-49	28.7 %	23.2 %	Manager/head R&D	37.8
50-99	16.5 %	5.2 %	Manager/head marketing	14.3
>=100	35.1 %	3.4 %	Other	12.8
Missing	5.5 %	9.8 %	Missing	5.2
Mean	89.5	14.8		

3.5 Measurement and Analysis Procedures

To find underlying factors underneath the 14 KI activities, a suitable method is factor analysis: the purpose of factor analysis is to discover simple patterns in the relationships among the variables. In particular, it seeks to discover if the observed variables can be explained in terms of a smaller number of variables called factors (Darlington, 2005). In order to limit bias introduced by using a single method, we applied both exploratory and confirmatory factor analyses in this study. We used SPSS 10.0 for exploratory factor analysis, using principal components analysis as the extraction technique and varimax as the method of rotation. For the confirmatory factor analysis we used LISREL 8.30. Goodness of fit (GFI), adjusted goodness of fit (AGFI), and relative chi-square (χ^2/df) were used as measures of fit. These measures are explained in the respective subsections in which they are discussed.

Convergent validity was evaluated 1) by identifying the smallest 'within stage' correlation and test whether it is significant; and 2) by testing whether all item-to-total correlations are positive and significant. Discriminant validity was tested for each KI activity by counting the number of times it correlated more highly with a KI activity of another function than with KI activities within its function (cf. Doll & Torkzadeh, 1988). Campbell and Fiske (1959) suggest determining whether this number is higher than half of all the comparisons. Although content validity cannot be tested statistically, the results of the Data

be judged in Table 3.2. As measurements of reliability we used Cronbach's alpha and inter-item correlation. As the questionnaire contained questions on the 14 activities for both technological knowledge and customer/market knowledge, all analyses were done for both types of knowledge. The results of these analyses are presented in Sections 3.6 and 3.7.

In order to further specify the outcomes of the factor analyses, we subsequently characterized for each factor the type of SMEs that scored high on that factor. By doing so, we hoped to be able to better explain why particular factors appeared in the factor analyses and thus, why particular patterns of KI activities appeared. This was done as follows:

1. The individual SMEs' scores on the factors were established by taking their mean score of those KI activities contributing to that factor. This resulted in a composite measure for each factor for each individual SME.
2. As a splitting point between high scoring SMEs and low scoring SMEs, we used the overall means for each factor.
3. For each factor, we compared the SMEs scoring higher than the overall mean score with those scoring lower, on each of the nine control variables presented in Subsection 3.3.3. This was done by, for each control variable, comparing the response patterns (frequency tables) of the high scoring SMEs with those of the low scoring SMEs. How we exactly made the comparisons, is better understood when Table 3.11 is observed.

To judge the significance of the difference between the high and low scoring groups we conducted a chi-square test in which the observed frequencies were compared with the expected frequencies. As the value of expected frequencies we took the sample sizes of the low and high categories of each function. For example, for function 1, 126 SMEs fell in the low category and 144 in the high category. Hence, the expected frequency percentages for this function were 126 / (126 + 144) = 47 % for the low category and 144 / (126 + 144) = 53 %. Using these values as expected frequency percentages is more accurate than the standard value of 50 %. The results of these analyses are presented in Section 3.8.

3.6 Results and Analysis

Mean values, standard deviations, and correlations between KI activities are given in Table 3.6, which is an efficient representation of two normal correlation tables, one for customer/market knowledge (N ≈ 220, normal font), and one for technological knowledge (N ≈ 270, italics). The second and third rows provide means and standard deviations for technological knowledge, the second and third column for customer/market knowledge. Rather than presenting variations, the diagonal provides correlations between identical KI activities for both types of knowledge (in bold).

Table 3.6 Correlation tables for customer/market knowledge and technological knowledge

			1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Mean		2.47	4.02	2.55	3.32	3.36	2.07	2.74	2.77	2.29	3.92	2.73	3.40	3.18	3.25
		S.D.	.82	.85	.92	.98	1.02	1.11	1.08	1.16	1.08	.82	.94	1.17	1.29	1.11
1. DISCOVER	2.83	.90	**.531****	-.170**	.191**	-.010	-.114	-.010	.029	-.089	.054	-.093	.063	.066	.005	.008
2. SEARCH	3.90	.90	-.189**	**.625****	.108	.179**	.242**	.115	.197**	.109	.045	.297**	.027	.152*	.210**	.143*
3. PRESENT	2.53	.94	.148*	.082	**.487****	.053	.025	.167**	.116	-.004	.125*	-.033	.122	.112	.183**	-.048
4. WRITTEN	3.11	.98	-.084	.317**	.204**	**.443****	.380**	.103	.181**	.130*	.090	.192**	.162**	.100	.161**	.076
5. PHYSICAL	3.13	1.11	-.085	.334**	-.016	.353**	**.637****	.147*	.267**	.224**	.140*	.218**	.128*	.182**	.190**	.322**
6. PEOPLE	1.95	1.06	-.014	.211**	.221**	.134*	.229**	**.667****	.250**	.323**	.420**	.130*	.001	.108	.233**	.075
7. COURSE	2.33	1.09	-.111	.194**	.152*	.182**	.238**	.236**	**.615****	.142*	.240**	.118	.070	.041	.215**	.123*
8. COOPERAT	2.58	1.14	-.003	.137*	.121	.185**	.196**	.264**	.140*	**.647****	.437**	.216**	.147*	.167**	.181**	.196**
9. OUTSOURC	2.11	.99	-.034	.208**	.094	.089	.189**	.352**	.209**	.335**	**.540****	.161**	.061	.058	.266**	.074
10. APPLICAT	3.75	.87	-.042	.300**	.002	.163*	.202**	.132	.033	.237**	.147*	**.686****	.218**	.138*	.231**	.224*
11. EXPLOIT	2.60	.85	.113	.096	.205**	.151*	.201**	.098	.043	.234**	.033	.227**	**.634****	.292**	.242**	.230**
12. STORAGE	3.26	1.09	-.009	.200**	.087	.221**	.295**	.097	.153*	.147*	.087	.272**	.408**	**.667****	.235**	.418**
13. DIFFUSIO	3.00	1.23	.008	.294**	.244**	.159*	.175*	.192**	.083	.117	.237**	.204**	.214**	.176*	**.819****	.333**
14. INTERNAL	3.06	1.08	-.052	.266**	-.002	.100	.298**	.092	.114	.146*	.034	.232**	.273**	.436**	.315**	**.789****

Normal font: results for customer/market knowledge; Italics for technological knowledge
* Significant at .05 level (2-tailed); ** Significant at .01 level (2-tailed)

3.6.1 Confirmatory Factor Analysis of the Three Knowledge Functions Model

Since the model used to develop the questionnaire contains three factors (the three KFs of identification, acquisition, and utilization), we started our analysis with a confirmatory factor analysis of this 3KF model. Additionally, we tested a model without underlying factors (0F model). As mentioned in Section 3.5, we used goodness of fit (GFI), adjusted goodness of fit (AGFI), and relative chi-square (chi-square divided by the degrees of freedom (χ^2/df)). GFI and AGFI should both be greater than .90 to accept a model and χ^2/df should be 2 or smaller (Garson, 2005).

Three Knowledge Functions Model

For technological knowledge, this analysis did not result in a fit, even after 1000 iterations. For customer/market knowledge there was a poor fit (GFI = .907, AGFI = .868, χ^2/df = 157.51 / 74 = 2.13). Also taking into account LISREL's suggested modifications did not substantially reduce χ^2. This leads to the conclusion that the full 3KF model does not fit the data.

Before concluding that the 3KF model should be rejected, we looked for potential modifications from a theoretical point of view (in contrast with LISREL's suggested modifications that are based on statistics). As shown in Table 3.6, most correlations for DISCOVER are negative (though mostly insignificant), while correlations for virtually all the other KI activities are positive. This seems to imply that DISCOVER does not fit into the 3KF model. Hence, the 3KF model was also tested with DISCOVER excluded. This slightly improved the results: The model showed a poor fit for both technological knowledge (GFI = .904, AGFI = .859, χ^2/df = 185.87 / 62 = 3.00) and customer/market knowledge (GFI = .914, AGFI = .873, χ^2/df = 135.04 / 62 = 2.18). Since, again, the 3KF model does not seem to fit the data, the 3KF model was rejected. Therefore, no further analyses were done on this model.

No Functions Model

A test of the 0F model with all KI activities separate (tested including and excluding DISCOVER) also resulted in a poor fitting model. The best fitting model (customer/market knowledge, DISCOVER excluded) scored GFI = .914, AGFI = .873, χ^2/df = 177.08 / 65 = 2.72. Since neither the 3KF model nor the 0F model resulted in a fit with the data, we continued the analysis with an exploratory factor analysis.

3.6.2 Exploratory Factor Analysis

In order to establish whether an exploratory factor analysis was an appropriate method for our data, we calculated the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy. The KMO indicates the proportion of variance that is common variance, i.e. which might be caused by underlying factors. For technological knowledge, the KMO was .717 and for customer/market knowledge the KMO was .741. Since values greater than .6 are regarded acceptable, we concluded that exploratory factor analysis could be applied to the data.

Without specifying the number of factors in advance, four factors emerged from the data (based on the 'Kaiser criterion' that only factors with eigenvalues > 1 should be counted as significant factors). Together, these factors explain 50.38 % of the total variance. Table 3.7 shows the factor loadings greater than .3 (loadings <.5 in parentheses). A factor analysis with unweighted least squares and maximum likelihood instead of principal components yielded the same factors, but with lower factor loadings.

Table 3.7 Rotated factor matrix of KI activities (principal component)

	Technological knowledge				Customer/market knowledge			
Item	**Com. 1**	**Com. 2**	**Com. 3**	**Com. 4**	**Com. 1**	**Com. 2**	**Com. 3**	**Com. 4**
3. PRESENT				.724				.797
1. DISCOVER				.667		(-.398)		.616
4. WRITTEN		.687				.624		
5. PHYSICAL		.655			(.400)	(.454)		
2. SEARCH		.629				.598		
10. APPLICAT		(.463)	(.302)		.547		(.346)	
7. COURSE	(.311)	(.462)				.660		
9. OUTSOURC	.807						.776	
8. COOPERAT	.725						.742	
6. PEOPLE	.714						.625	
12. STORAGE			.734		.727			
14. INTERNAL			.716		.709			
11. EXPLOIT			.634		.672			(.335)
13. DIFFUSIO			(.462)		(.369)	(.314)		

Since, for technological knowledge, there are only two KI activities with factor loadings above .3 on more than one factor and most factor loadings are greater than .6, there seem to be four distinct factors in the data. Based on the similarities between the KI activities loading onto a factor, we chose the following labels for the four factors: 'passive search' (PRESENT and DISCOVER), 'goal attainment' (WRITTEN, PHYSICAL, SEARCH, APPLICAT, and COURSE), 'cooperation' (OUTSOURC, COOPERAT, and PEOPLE) and 'integration' (STORAGE, INTERNAL, EXPLOIT, and DIFFUSIO). We will refer to these four factors as the 4F model. For the moment, we remain undecided about the nature of these functions (i.e. knowledge or system functions). Also, the labeling is temporary and only used to be able to refer to the four factors of the model. The nature and final labeling of the four factors will be specified after further analysis and confrontation with the results of Chapter 2.

For customer/market knowledge a very similar model appears. The emerged factors explained 52.84 % of total variance and were similar to technological knowledge, except for APPLICAT, which loaded onto 'integration' instead of 'goal attainment' with factor loading .547. A possible explanation for this difference is that most high-tech SMEs are technology-oriented firms that develop and produce products using a specific technology. For them, customer/market knowledge is important for knowing what products to develop but less for knowing how they can be developed. Hence, the application of customer/market knowledge is more supportive than directly needed for NPD. Similarly, whereas technological knowledge is at the center of their goal attainment, customer/market knowledge is more supportive as part of the integration function.

3.6.3 Confirmatory Factor Analysis of the Four Functions Model

The 4F model emerging from the exploratory factor analysis was tested in a confirmatory factor analysis. Again, this did not result in a fit. Statistically this is explained by the positive correlations of DISCOVER and PRESENT (together 'passive search') and the negative correlations of DISCOVER and other KI activities. Semantically it can be explained by the passivity of the two activities contrasting with the more active character of other activities. When 'passive search' was omitted, the fit of the model improved. Based on LISREL's suggested modifications we tested five variations, of which Table 3.8 presents the results:

- Model A: 12 separate KI activities (DISCOVER and PRESENT excluded), no functions.
- Model B: 3 functions, 'passive search' excluded, COURSE under 'goal attainment'.
- Model C: similar to Model B, but COURSE under 'cooperation'.
- Model D: similar to Model B, but error covariance between DIFFUSIO and STORAGE.
- Model E: similar to Model C, but error covariance between DIFFUSIO and STORAGE.

Because of the results of the factor analysis, for each model, APPLICAT is included under 'goal attainment' for technological knowledge and under 'integration' for customer/market knowledge.

Table 3.8 Confirmatory factor analysis for variations of the 4F model

	Technological knowledge (N ≈ 270)					Customer/market knowledge (N ≈ 220)				
Model	*GFI*	*AGFI*	X^2	*Df*	X^2/df	*GFI*	*AGFI*	X^2	*Df*	X^2/df
Model A	.888	.838	204.11	54	3.78	.902	.859	143.17	54	2.65
Model B	.945	.916	93.50	51	1.83	.948	.921	72.01	51	1.41
Model C	.944	.915	95.21	51	1.87	.948	.921	72.31	51	1.42
Model D	.948	.920	87.82	50	1.76	.955	.930	62.25	50	1.25
Model E	.947	.918	90.12	50	1.80	.955	.929	62.60	50	1.25

As Table 3.8 shows, Model D is the best fitting model for both types of knowledge. These models are depicted in Figures 3.1 and 3.2. A possible explanation for the negative error covariance between STORAGE and DIFFUSIO is that the two KI activities are substitutes rather than complements. We will come back to this later.

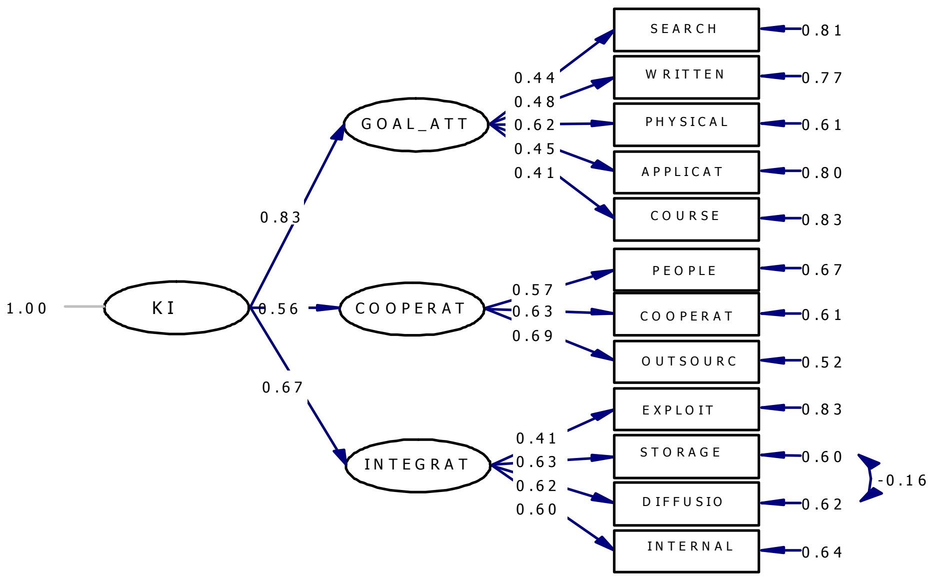


Figure 3.1 Model D for technological knowledge

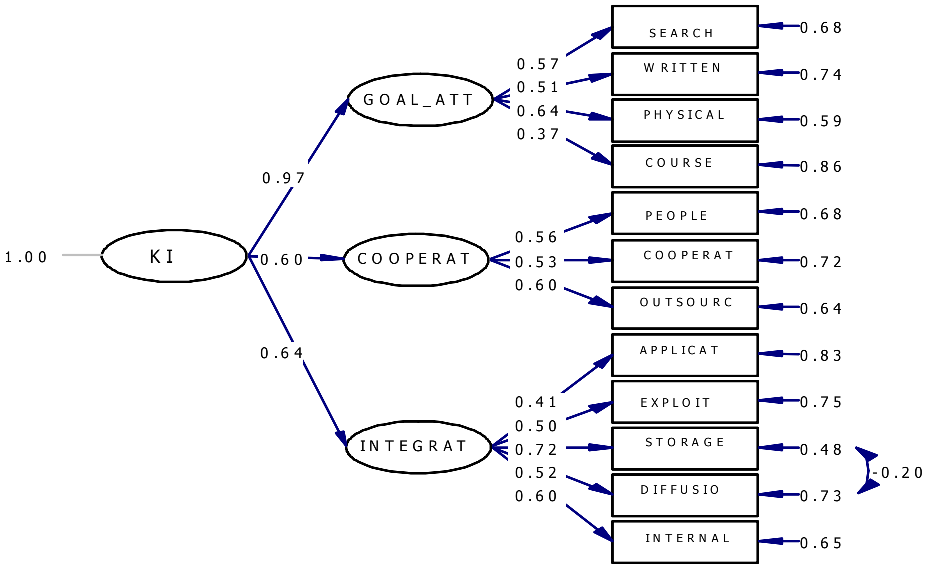


Figure 3.2 Model D for customer/market knowledge

3.6.4 Reliability, Convergent and Divergent Validity

Because SPSS does not allow modeling error covariance, Model B was used instead of Model D to analyze reliability, convergent validity and discriminant validity. The addition of an error covariance improved the fit of the model, but did not change the model in terms of the grouping of KI activities onto factors. Therefore, we believe that using Model B instead of Model D does not substantially affect the analyses below. Cronbach's alphas, average inter-item correlations, and lowest and highest item-to-total correlations are presented in Table 3.9 and discussed below.

Table 3.9 Reliability and convergent validity coefficients

	Technological knowledge					Customer/market knowledge				
Model B	Valid N	Items	Cronb. α	Avg.inter-item corr.	Item-total corr.[1]	Valid N	Items	Cronb. α	Avg. inter-item corr.	Item-total corr.
GOAL_ATT	254	5	.58	.22	.27 - .42	215	4	.59	.27	.28 - .43
COOPERAT	262	3	.66	.39	.43 - .53	215	3	.59	.32	.37 - .45
INTEGRAT	258	4	.62	.29	.35 - .48	210	5	.64	.26	.32 - .48

[1] Range, indicated by lowest and highest item-to-total correlation

Cronbach's alphas did not reach the recommended 0.7. However, considering that, ceteris paribus, Cronbach's alphas automatically increase with the number of items, we think alphas of about 0.6 are sufficiently high to be at least interesting for the small number of items per function. Moreover, also because of the exploratory stage of our analyses – we did not intend to test the 4F model in advance – we believe these alphas are sufficiently high to be interesting for this study.

Table 3.6 showed that the smallest 'within-function' correlations are all significant at .05 level and most at .005 level. Moreover, as shown in Table 3.9, all item-to-total correlations are positive and significant. Together, these results suggest a moderately reasonable convergent validity. To test discriminant validity we counted the number of times the correlation of items between functions was higher than within a function. This yielded 11 out of 66 possible violations for technological knowledge and 8 out of 66 possible violations for customer/market knowledge. Given that this is considerably less than the suggested upper bound limit of 50 % (Campbell & Fiske, 1959), we conclude discriminant validity also to be reasonable.

In sum, we can conclude that the fit of the 4F model that emerged from the exploratory factor analysis is by no means perfect. However, considering that it appeared from an exploratory analysis and that it was reproduced for two types of knowledge, the fit of the 4F model is at least sufficiently interesting to further investigate.

3.7 The Four Functions Model: Knowledge or System Functions?

In the preceding chapters we have introduced two types of functions according to which KI activities could be patterned: knowledge functions (KFs) and system functions (SFs). The analyses so far have rejected the 3KF model and have suggested an alternative 4F model. In this section we will investigate whether this 4F model concerns KFs or SFs or neither.

3.7.1 Knowledge Functions and the Four Functions Model

As the analyses have shown, the data did not fit the 3KF model. This suggests that, in practice, KI is not organized according to these KFs. However, there are at least four reasons that this does not mean that we should reject KFs as a relevant concept for KI.

1. The data might be wrong; instead of rejecting the KF model we should reject the data.
2. The 3KF model was only one of the available KF models that were mentioned in Chapter 2. It is still possible that the 4F model fits one of the other KF models mentioned in that chapter.
3. It might be possible that the 4F model is a KF model that was not previously mentioned in the literature.
4. The observation that KFs are not reproduced in practice does not mean they don't exist. Even if none of the KF models of Chapter 2 fits the data of the empirical study, KFs still are a way of classifying KI activities theoretically.

Ad. 1. Data vs. Theory

With respect to the first option, we never can be sure whether the data is wrong, or the model (Davidsson, 2004). While the theoretical basis of the three KFs was rather strong – they were based on well-established economic theories of resource allocation – using the three functions to find empirical patterns of KI activities, to our knowledge, has not been done before. This suggests that the proposition that KI activities are patterned according to the three KFs is only an exploratory proposition. On the other hand, the procedures for the data collection and analysis of the empirical study were carefully designed according to scientific guidelines. Moreover, response bias was unlikely and the 3KF model was rejected for both technological and customer/market knowledge. Considering these arguments, we put our bets on the data rather than the 3KF model.

Ad. 2. Data vs. Existing Knowledge Function Models

When we compare the results of the factor analysis with the KF models that were discussed in Subsections 2.3.3 and 2.4.1 (respectively concerning subsystems and patterning of KI activities), we observe that none of the KF models from the literature fits the 4F model. The models that perhaps come closest are those of Stenmark (2001) and Wilson (1981). Stenmark distinguishes four functions of intranets: they are awareness space, information space, communication space, and collaboration space. When we map these four spaces onto the 4F model, passive search seem to fit the awareness space and cooperation seem to fit the collaboration space. However the other two spaces do not seem to match. Wilson distinguishes four information processes: information seeking, information exchange, information transfer, and information use. When we compare these processes to the 4F model it seems that passive search fits information seeking, goal attainment fits information transfer, cooperation fits information exchange and integration fits information use. However the match between the two models is very weak since in the data, for example, search is included in the goal attainment function and not in the passive search function, as we would expect when it matches Wilson's information seeking process. Thus, we can conclude that the 4F model does not match any of the KF models presented in Subsections 2.3.3 and 2.4.1.

Ad. 3. Data vs. other Knowledge Functions

A third option is that the 4F model represents a KF model that has not been recognized in existing literature so far. When true, this should mean that each of the four functions in the 4F model has a different effect on the knowledge concerned and that the KI activities within a function have a similar effect on the knowledge concerned. A quick view at the four functions shows that this is not the case. For example, in the goal attainment function, knowledge is found (by means of the SEARCH activity), transferred (by means of the WRITTEN and PHYSICAL activities), and put into practice (by APPLICAT), which are three different functions from a knowledge perspective. Hence, we conclude that the 4F model is not a KF model and thus that the data do not fit any KF model.

Ad. 4. Data and Theory

Since none of the first three options seems to hold, we accept the fourth option. That is, KFs are not reproduced in the empirical results of this study, but can still be a theoretically valid means to classify KI activities and to explain the function they have for knowledge. Since this chapter concerns an empirical study, in which the KFs were not reproduced, for the moment we leave the KFs for what they are. We will return to them in the next chapter and concentrate now on SFs.

3.7.2 System Functions and the Four Functions Model

After our conclusion that the 4F model is not a KF model, the question arises whether it is an SF model. To answer this question there are four options that are similar to the four options for the KFs mentioned above.

1. The 4F model fits one of the SF models mentioned Chapter 2.

2. The 4F model is an SF model that was not previously mentioned in the KI literature.
3. The 4F model is not an SF model but might be a third type of model (in addition to KF and SF model) that was not anticipated in this study.
4. No theoretical model can be found that accounts for the 4F model.

As we discuss below, the 4F model fits one of the SF models that were mentioned in Chapter 2. This means that we do not have to consider the second, third, and fourth option.

When we review the SF models of Chapter 2, the 4F model shows an interesting resemblance to the four SFs of Stein & Zwass (1995) and its underlying models (Parsons, 1977; Quinn & Rohrbaugh, 1983). The four SFs, adaptation, goal attainment, integration, and pattern maintenance, were described in Subsection 2.3.3. The resemblance is most apparent for the goal-attainment functions in both models, which are defined as "[...] the ability of the organization to set goals and evaluate the degree of their fulfillment" (1995: 96). Although goal setting and evaluation were not explicitly included in the current study, searching, acquiring by documents and files, analyzing products, following courses, and using knowledge for the goal it was acquired for seem clearly elements of a KI goal attainment function. Another similarity is between the integrative functions of both models, which are defined as "[...] the organizational coordination and management of information across the organization" (1995: 96). Storing, diffusing, and internalizing knowledge to reuse it typically contribute to this function. The similarity between the pattern maintenance function and our cooperation function is less apparent, though still present since both are concerned with human relations. Stein & Zwass have defined this function as "[...] the ability of the organization to maintain the cohesion and the morale of the workforce" (1995: 96). Although this definition concentrates on human *resources*, the underpinning model of Quinn & Rohrbaugh (1983) is a human *relations* model. When comparing the three KI activities grouped under this function (hiring people, cooperation, and outsourcing) to the other KI activities, they distinguish themselves by their focus on a strong and long-term relationship between source and seeker. Because the focus of the current study is on external knowledge, it is not surprising that these three KI activities regard external human relations, whereas Stein & Zwass and Quinn & Rohrbaugh regard internal human relations. Thus, though the pattern maintenance function and the cooperation function are not identical, they have considerable common features. This leaves us with one potential pair of functions: the adaptive function of Stein & Zwass and the passive search function of the current study. Stein & Zwass' definition of the adaptive function is "[...] the ability of the organization to adapt to changes in its environment" (1995: 96). Both Stein & Zwass and Quinn & Rohrbaugh emphasize the openness and receptivity of an organization as important features of this function. Although the two passive search KI activities in the current study (accidental discovery and unsolicited presentation of knowledge) are more passive than Stein & Zwass' definition of the adaptive function, the aspect of receptivity is clearly recognizable. Consequently, we can conclude that the 4F model that appeared from the data resembles a SF model with a long history. Hence, we will call it a 4SF model from now on.

Although our arguments and empirical backing above are not conclusive, we believe the results provide sufficient reason to further analyze KI from the perspective of the 4SF model: both the results of the literature review of Chapter 2 and the empirical patterning of KI activities in the current chapter point in the direction of the 4SF model of Stein & Zwass and its underlying models of Quinn & Rohrbaugh (1983) and Parsons (1959). While a further theoretical analysis of the 4SF model is postponed to the next chapter, the next section provides further analyses of the empirical data from the perspective of the 4SF model.

3.8 Characterization of the Four System Functions Model

In order to further specify the 4SF model that was found, this section characterizes the type of companies that is performing the four SFs. Such characterization can provide us with better insights in the SFs. For example, it can help to find an explanation why certain respondents score high on one function and other respondents on other functions.

Starting with technological knowledge, this section compares for each function the high and low scoring SMEs. As discussed in Section 3.5, the overall mean score for each function was used as the splitting point between high and low scoring SMEs. These mean scores are the overall mean scores of the KI activities that contributed to a particular function. They are given in Table 3.10.

Table 3.10 Overall mean scores for the four functions (technological knowledge)

	N	Minimum	Maximum	Mean	Std. Deviation
Passive search	272	1.00	4.50	2.5129	.6729
Goal attainment	278	1.25	5.00	3.4878	.6086
Integration	272	1.00	5.00	2.4081	.8900
Cooperation	270	1.00	5.00	3.1574	.7883

Using these mean scores as the splitting point, we compared the SMEs that scored low on a function with the SMEs that scored high on that function on nine control variables. The complete results of these comparisons are included in Appendix VI. Below, in Table 3.11, we have only included the significant results (p=.05). In this table, the value 30.2 in the cell 'Netherlands – low passive search' means that 30.2 % of the SMEs scoring low on passive search are Dutch. Hence, from the SMEs scoring high on passive search, 45.2 % is Dutch.

The reader might remark that for the passive search function the number of SMEs scoring lower than average (N=170) is almost twice as large as the number of SMEs scoring higher than average (N=89). The reason is that it is a composite measure of two KI activities, implying that only nine possible values are possible (1, 1.5, ..., 5). Considering that the mean score is 2.51 (see Table 3.10) and that a majority of respondents (83) scored 2.50, many respondents are categorized in the low category.

As presented in Table 3.11, there are only minor differences between the high and low scoring groups of SMEs for each of the four functions. Only 9 out of the 51 x 4 = 204 comparisons (4 %) yields a significant difference at p=.05 level. At the .01 level there is not a single comparison that shows a significant difference between the high and low scoring groups of SMEs.

Table 3.11 Significant frequency percentages for the control variables by system functions

	Passive search			Goal attainment			Cooperation			Integration		
	Low	*High*	*Sig.*	*Low*	*High*	*Sig.*	*Low*	*High*	*Sig.*	*Low*	*High*	*Sig.*
N ≈ ...	**170**	**89**		**128**	**137**		**146**	**114**		**119**	**138**	
Country												
Germany							26.8	14.3	.027			
Netherlands	30.2	45.2	.048									
Size												
2-9										20.2	8.8	.015
10-24										10.1	21.2	.027
Age												
Industry												
29 Machinery				40.0	23.0	.013						
% sales new products												
Main product												
Consumer products							14.2	6.1	.046			
Software				3.9	10.9	.037						
Production process												
% R&D employees												
5-10 %	15.4	29.4	.020									
% Academic degree												
21-40 %	16.4	6.9	.048									

Consequently, we can conclude that the four functions cannot be characterized by means of the SMEs that perform them. More importantly, this seems to imply that, at the level of analysis of this study, KI is similar in companies of different sizes, countries, ages, etc. This observation is consistent with earlier research on information seeking, for example Shuchman who found (for large enterprises) "[...] that information problems are consistent across all industries in the Unites States and are experienced by engineers of all ages in all kinds of jobs, trained at all levels of engineering education (1981: 3). Moreover, a review of information-seeking behavior of engineers by Pinelli et al. showed that "[...] despite the extraordinary diversity in practice, engineers use information in essentially the same ways (Kwasitsu, 2003: 460). Similar conclusions are drawn by Rosenbloom & Wolek (1967) and Ellis & Haugan (1997). The preliminary interviews described above also yielded the same conclusion.

Since the 4SF model was almost similar for technological knowledge and customer/market knowledge and because of the lack of significant differences in the comparisons above, we will not discuss the customer/market knowledge. The analyses have shown that also for customer/market knowledge there are virtually no significant differences between the high and low scoring SMEs.

3.9 Discussion and Conclusion

This chapter started with the research question '*To what extent does an additional empirical study on KI provide the empirical material that is missing in the current literature?*' More specifically, the chapter looked for empirical patterns of KI activities and a basis for selecting a theoretical framework to be used to construct the systemic KI model. Based on a two-stage research approach consisting of exploratory interviews and a large-scale survey the chapter provides the following answers to this research question.

With respect to the patterning of KI activities, the study has shown that practice provides indications for a 4F model consisting of the functions ‘passive search’, ‘goal attainment’, ‘cooperation’, and ‘integration’. Moreover, the results of the empirical study of this chapter show that the indications for these four functions are reproduced for the two types of knowledge under study: technological knowledge and customer/market knowledge. It was also shown that the results do not significantly differ between SMEs characterized by a number of control variables, including of country, size, age, and industry.

With respect to the selection of a theoretical framework, it has appeared that the 4F model that emerged from the factor analyses shows remarkable resembles with one of the SF models discussed in Chapter 2. Both the results of the literature review of Chapter 2 and the empirical patterning of KI activities in the current chapter point in the direction of the 4SF model of Stein & Zwass and its underlying models of Quinn & Rohrbaugh (1983) and Parsons (1959). This systemic model distinguishes four SFs: adaptation, goal attainment, integration, and pattern maintenance. Although the fit of the empirical results and the 4SF model of Stein & Zwass is not perfect, considering the limitations of the empirical study (for example, it was part of a larger study, the 4SF model was not anticipated, and systemic KI theory is immature), we believe the 4SF model appeared sufficiently stable to continue this study with this model. Hence, we will adopt Parsons’ terminology from here on.

Although the empirical study did not show any empirical corroboration of an KF model, this does not reject the existence or relevance of such model in practice. By definition, KI activities have KFs for the knowledge they operate on. The results of the empirical study only suggest that KI activities seem not to be *empirically patterned* according to KFs. This seems to imply that SMEs organize KI according to SFs rather than to KFs. Since practice has not provided indications for another KF model than the 3KF model resulting from Chapter 2 (consisting of the identification, acquisition, and utilization of knowledge), we have found no reason to drop the 3KF model at this moment. Therefore, the contribution of KI activities to KFs and SFs can now be specified as follows (see Figure 3.3):

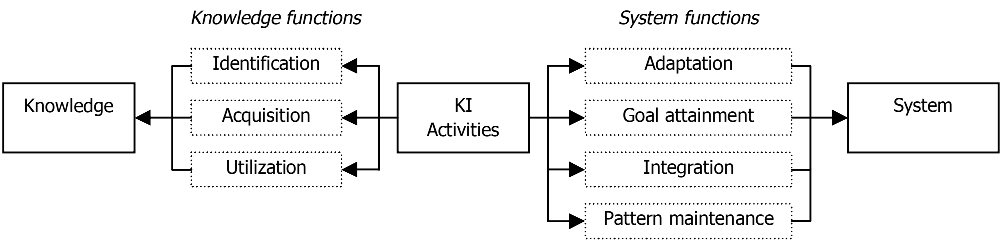


Figure 3.3 KI activities contributing to knowledge functions and system functions

The next chapter analyzes this model extensively and specifies it by discussing its theoretical origins. Moreover, it invokes the other characteristics of a systemic KI model that were discussed in Chapter 2. Considering that Stein & Zwass model is based on Quinn and Rohrbaugh’s analysis of organizational effectiveness, which are both based on Parsons’ social system theory, the next chapter will elaborate on Parsons’ work extensively and use it as a framework for developing a systemic KI model.

CHAPTER 4: DESIGN OF A SYSTEMIC KI MODEL

"Logically deduced theories based on ungrounded assumptions, such as some well-known ones on the social system and on social action can lead their followers far astray in trying to advance sociology."

Glaser & Strauss (1967: 4)

"There is much to be said for the re-reading of older works – particularly in an imperfectly consolidated discipline such as sociology – providing that this study consists of something more than that thoughtless mimicry through which mediocrity expresses its tribute to greatness."

Merton (1967: 37)

4.1 Introduction

With Chapters 2 and 3 we have concluded the first phase, the analysis, of the three-phase approach of this study and have answered the first research question. Together, these chapters have provided us with all the ingredients for building a systemic KI model: we have systemic characteristics from the literature, we have supplementary characteristics from practice, and we have a common theoretical model to which these characteristics point: Parsons' social system theory. In this chapter we will use these ingredients in order to develop a systemic KI model. The research question to be answered in this chapter is: '*What systemic KI model can be derived from the framing of the gathered material into Parsons' social system theory?*' The two subquestions are:

a. To what extent is Parsons' social system theory applicable to the KI context?
b. What systemic KI model can be derived from the framing of the gathered material into the applicable part of Parsons' social system theory?

In order to answer these research questions, the chapter is organized as follows: Section 4.2 sets the stage by providing a short overview of the backgrounds of Parsons' theory and its critiques. Thereafter, Section 4.3 explains the approach that was followed in answering the research questions. Subsequently, Sections 4.4, 4.5, and 4.6 explain respectively the structural, the behavioral, and the control characteristics of KI by invoking Parsons' theory (RQ2a) and translating it to the KI context (RQ2b). Finally, the chapter ends with a discussion and conclusion in Section 4.7.

4.2 Parsons' Theory and its Critiques

Before we start developing the systemic KI model it is necessary for two reasons to shortly elaborate on Parsons' theory and its critiques. Firstly, we assume that the reader is not familiar with Parsons' theories. By providing an overview of this complex theory, it will be easier to follow the arguments made in this chapter. Secondly, some parts of Parsons' theory are highly controversial and are sometimes misinterpreted. Therefore, we feel we should highlight the critiques and argue why we still adopt Parsons' theory in this study.

4.2.1 Overview of Parsons' Theory

This subsection summarizes the ideas of Parsons' social system theory that are used within this study. By no means is this a complete summary of Parsons' rich and complex theory. Rather, it is a selection of those aspects of the theory that help the reader to grasp Parsons' view on social systems. According to Parsons, a system is "[...] any set of interdependent elements that coheres into a self-regulating whole and is maintained by drawing resources from an environment" (Parsons & Mayhew, 1982: 24). More specifically, a living system – which a social system is – is "[...] one which maintains a pattern of organization and functioning which is both different from and in some respect *more stable* than its environment" (Parsons, 1977: 230, original italics). Or even more specifically, "A social system consists in a plurality of individual actors interacting with each other in a situation which has at least a physical or environmental aspect, actors who are motivated in terms of a tendency to the "optimization of gratification" and whose relation to their situations, including each other, is defined and mediated in terms of a system of culturally structured and shared symbols" (Parsons, 1964: 5-6).

While this definition of a social system helps us to understand what a social system is, Parsons' theory goes far beyond this. Its key ideas and assumptions can be summarized as follows (Parsons, 1937; Parsons, 1959; Parsons, 1961; Parsons, 1964; Parsons, 1977; Parsons & Mayhew, 1982; Parsons et al., 1961):

- Society consists of a structural hierarchy of systems that are part of supersystems and that can be decomposed into subsystems until there is at the lowest level the individual actor.
- (Sub)systems consist of structure and process, which are both relative concepts. Structure is that part which is stable in a given timeslot and for a given aspect; process is the part that is changing during that timeslot for that given aspect. (Parsons, 1977: 103).
- Together, structure and process determine the function of a system: "The concept *function* is not correlative with *structure*, but is the master concept of the framework for the relations between any living system and its environment. Functions are performed, or functional requirements met, by a combination of structures and processes" (Parsons, 1977: 236, original italics).
- Systems on each level have different roles (or functions) within their supersystem. This means that they are specialized. Each function can be traced back to one of four general functions of adaptation, goal-attainment, integration, and pattern maintenance.
- Because the systems are specialized, they are dependent on each other. They need input from other systems and need to create output for other systems. Systems need to interact with each other in order to receive their gratification. This implies that the systems are open systems: they have permeable boundaries over which they affect each other.
- Interactions between systems, subsystems, or individual actors consist of a double interchange of, on the one hand, resources that are generated, allocated, and utilized and, on the other hand, generalized media. The example Parsons uses here repeatedly is the interaction between households and business: households provide labor (resources) for wages (generalized media) and use this money (generalized media) to buy products (resources) of businesses.

- Within a system, actors strive for gratification. While actors pursue their self-interest and their own satisfaction, that is not their sole concern. Rather, there is a strong measure of agreement among actors, they do get along with, cooperate with, and help each other. Moreover, their behavior is socially and morally regulated, with views of right and wrong, proper and improper, and appropriate and inappropriate.
- By means of the generalized media actors can get others to comply with their demands in four ways: inducement by rewards (money), deterrence by negative sanctions (power), persuasion by offering reasons (influence), and invoking existing commitments (commitments).
- There may be external or internal influences that drive the system out of its equilibrium. Internal influences are related to the incompatibility of the four functions (Parsons & Mayhew, 1982: 60). External influences consist of changes in the environment of the system. These influences trigger adjustments in the various parts of the system that return the system to a state of equilibrium.
- Change tends to be orderly and evolutionary, rather than revolutionary or with dramatic structural breaks. Conflicts or external factors stimulate adjustment of the parts to move toward a new equilibrium.
- While changing, systems become increasingly differentiated. On the one hand, this leads to a larger number of conflicts between subsystems, on the other hand this leads to conflicts that are less strong (Alexander, 1983: 143). The increased differentiation requires increased coordination and integration between subsystems.

In this overly simple summary of Parsons' social system theory, we recognize many of the characteristics of systems that were presented in Subsection 1.2.2, though more specific. In the remainder of this chapter we will elaborate further on those parts of Parsons' theory that are relevant for this study. We deem those parts relevant that relate to the seven characteristics for systemic models that were presented in Subsection 1.2.2. However, first we will summarize some of the critiques to Parsons' theory.

4.2.2 Some Critiques

Parsons' social system theory has not been accepted unanimously and enthusiastically by all sociologists after him. On the contrary, since his early – and sometimes controversial – ideas, Parsons' writings have led to enormous debates. Also we do not adopt all of Parsons' ideas unaltered. However, we believe there is too much value in them to simply ignore them. Also, we believe that Parsons' ideas have been misinterpreted, oversimplified, and distorted. Below we will summarize some of the critical assertion made about Parsons' theory and respond to them.

Too Grand to Be Useful

Captained by one of Parsons' students, Merton, Parsons' theories are often criticized for being too grand and general to be useful. According to Merton, striving for grand all-overarching frameworks and theories is a hopeless quest. Rather, we should try to develop 'theories of the middle-range', which are "theories intermediate to the minor working hypotheses evolved in abundance during the day-by-day routines of research, and the all-inclusive speculations comprising a master conceptual scheme from which it is hoped to derive a very large number of empirically observed uniformities of social behavior" (Merton, 1968: 5-6). Merton's critique to Parsons is that he is exclusively trying to do the latter.

In a response to this critique, we observe that Parsons (1959) does not deny the importance of middle-range theories. Rather, he argues that many theories of the middle-range could not have been achieved without general theory. Furthermore, according to Parsons, general theory has produced a whole range of middle-range hypotheses. Also, when he applies his general theory to a variety of empirical phenomena, Parsons tries to link the two levels. An example is the application of his theory to organizations (Parsons, 1956a; Parsons, 1956b). While not always successful in this (see 'Too Deductive') he most certainly does not stay at the level of general theory (Alexander, 1983).

We believe that Parsons' theory might indeed be too grand to apply directly, but that it is possible and useful to derive middle-range theories from it. This also is the way we use Parsons' theory in this study. As argued before, we use his theory as a general framework to structure the more specific KI literature. The outcome is a systemic KI model at the middle-range level. Hence, we believe that this first critique on Parsons provides no reason to avoid the use of his theory in this study.

Too Deductive to Be Useful

A second critique to Parsons' work is that it is too deductive (e.g. Glaser & Straus, 1967). An example is Parsons' attempt to apply the four function framework to a large variety of phenomena, including 'general action', 'culture', 'scientific knowledge', and 'personality', which, according to Alexander (1983), does not work because they do not possess the characteristics of a social system. The critique of being too deductive seems to be particularly widely shared amongst both his followers and his critics when it concerns Parsons' discussion about the 'media of interchange' (money, power, influence, and value commitments). Parsons deduces these four media of interchange from the four functions of a social system. Moreover, he generalizes the properties of money to the remaining three media (Chernilo, 2002; Künzler, 1989). There seems to be almost unanimous agreement (Alexander, 1983; Chernilo, 2002; Habermas, 1987; Künzler, 1989; Luhmann, 1977; Luhmann, 1995) that, in this way, Parsons reduces the notion of generalized media too a much more limited position in sociology than it deserves. How we will deal with generalized media, will appear in Subsection 4.5.2.

Concerning this second critique to Parsons' work, we agree with the widely shared view that Parsons' is, at times, too deductive. This is, however, not to deny the potential usefulness of Parsons' complete theory to the KI context. What it implies, is that we should be careful in thoughtlessly adopting Parsons' theory unmodified to this particular context. We try to avoid this in this chapter by comparing Parsons' theory to the KI literature and the empirical results and treating them as equally important, rather than by forcing the latter two to fit Parsons' theory. Also, we have not simply assumed that Parsons' theory would be relevant to the KI context. On the contrary, the relevance of his theory was indicated by our empirical study.

Too Little Empirical to Be Useful

A related, but different critique is that much of Parsons' work has no empirical basis. Part of this critique stems from Parsons' deductive approach where he derives middle-range theories from general theories. Also his explicit denial of empiricism and positivism in data collection may have fed this critique (Parsons & Mayhew, 1982: 77). However, in his research, Parsons uses massive amounts of empirical data and there is a strong connection between Parsons' deductive theories and the empirical data he collects. Parsons has been, however, very inconsistent and confusing about the role of empirical data and the method to gather them (Savage, 1981). The probably best way to characterize Parsons' use of empirical data is that he uses it "[...] in the manner of the classical theorists, to illustrate, to elaborate, and to specify his fundamental theoretical commitments. He does so, like Kant, in order to demonstrate how these fundamental categories are imbedded in the real world" (Alexander, 1983: 45).

Another aspect of this critique is that Parsons' social systems theory refers rather to system as an aspect rather than as a concrete empirical phenomenon. "The concepts are analytical rather than concrete. The claim is that, whether a system has or has not developed a bounded, specialized apparatus for dealing with a given functional problem, the problem must be dealt with somehow; it is therefore legitimate to speak analytically of, say, the integrative subsystem of a social system, whether or not the system has a clearly demarcated organization for dealing specifically with integrative problems" (Parsons & Mayhew, 1982: 30). Because Parsons refers to analytical rather than concrete empirical systems, the link between his theory and the empirical phenomena to which it should be applicable is not always clear.

Regarding this third critique, it is important to realize that Parsons uses empirics mainly for theory building, not for theory testing. Although, today, there are clearly defined methods for using empirical data in theory testing, there are hardly such methods for using empirical data in theory building. The main guideline seems to be to collect as much data as possible (e.g. Dubin, 1978). Since this is what Parsons has done, we believe that this critique forms no reason to avoid the use of Parsons' theory. In this study, we aim at the development of a systemic model that is more specific than Parsons' theory. Hence, the link between theory and empirics is more evident than in Parsons' case. Moreover, by specifying our research methods in the two empirical chapters (Chapters 2 and 5) we have tried to be as clear as possible about the way we use empirical data in the development of the systemic KI model. By explicating our methods, this third critique should not be applicable to this study.

Too Deterministic and too Anti-Deterministic to Be Useful

One of the severest critiques to Parsons' theory is that it reduces the role of individuals to simple pawns within the system that are there to fulfill their function. Giddens remarks about this that "there is no doubt that in his theoretical scheme the object (society) predominates over the subject (the knowledgeable human agent)" (Giddens, 1984: xx). A related critique of Giddens is that, although Parsons calls his theory 'a theory of action', there is too little focus on action in his theory. "[...] what I would regard as a satisfactory conception of action (and other related notions, especially those of intentions and reasons) is not to be found in Parsons's work. [...] Little, if any, conceptual room is left for what I emphasize as the knowledgeability of social actors, as constitutive in part of social practices"

(Giddens, 1984: xxxvii). On the other hand, Parsons' theory also is criticized for being too idealistic, or *anti*-deterministic, which is exactly the opposite critique (see Savage, 1981, for a summary of these critiques).

The contradictory nature of these two opposing critiques, makes us expect that the 'truth' lies somewhere in the middle. When we consider Parsons' work, we see that Parsons' indeed aims in between these two extremes. Parsons explicitly distinguishes between individuals as actors (with will) and individuals as objects (without will) (Alexander, 1983: 43). Parsons also explicitly positions himself between deterministic (positivistic) theories of action (no freedom of choice for the individual) and idealistic theories of action (complete freedom of choice for the individual). He promotes a voluntaristic theory of action in which the individual often chooses voluntary to conform to expectations of the system (Parsons, 1937: 80). In this theory, it is the relation between the deterministic and the idealistic aspects of action that are central (Savage, 1981). Given Parsons' focus on this relation rather than on a deterministic or anti-deterministic theory of action, we believe that this fourth critique does not hold. Therefore, this critique gives no reason to abandon Parsons' theory in this study.

Too Much Focus on Equilibrium to Be Useful

A fifth critique of Parsons is that he is concentrating too much on equilibrium and too little on conflict (e.g. Merton, 1968). Again it is Giddens who is one of the fiercest critics: "Functionalism and naturalism tend to encourage unthinking acceptance as societies as clearly delimited entities, and social systems as internally highly integrated unities. [...] But 'societies' are very often not like this at all" (Giddens, 1984: xxvi-xxvii). Similar critiques are made by Gouldner (1971), Lockwood (1956) who argue that conflict and social change are not sufficiently addressed in Parsons' theory.

Other scholars explicitly argue that these critiques do not hold. For example, according to Alexander, "Parsons is not unequivocally committed to social harmony, as evidenced, for example, by his distinction between 'static' and 'moving' equilibrium, or his periodic empirical analysis of social conflict and breakdown" (Alexander, 1983: 295). And, "Parsons' perspective does not focus on integration alone, nor does it assume consensus. To the contrary, it effectively articulates some of the most basic social antagonisms" (Alexander, 1983: 71). Also Savage shows "[...] quite categorically [...] that social change *is* a central issue for Parsonian theory" (Savage, 1981: 199, original italics).

We agree with the latter group of scholars. An example of how conflict is included in Parsons' theory concerns the four functions that he distinguishes. The interests of these functions are conflicting. For example, while the pattern maintenance function strives for stability, the adaptive function keeps a system open to disturbances of the system's environment. Also, "[...] the concept of the social system, and its related concepts of order and equilibrium [...] are seen by Parsons to be the means of analyzing both relatively stable societies *and* those which are subject to rapid or severe transformation." (Savage, 1981: 145-146, original italics). However, we do believe that Parsons seems to underexpose extreme and revolutionary forms of conflict, like in Merton's (1968) concept of rebellion as individual adaptation mode towards pressures in a system. Considering that 1) we expect these extreme forms of conflict and change are rare in KI, 2) that we have found no examples of it in the literature or the exploratory interviews, and 3) that Parsons' theory does include less extreme forms of conflict and change; we believe that this fifth critique is not relevant for this study.

Finally: Too Confusing to Be Useful

A final comment and widely agreed upon comment is that Parsons' work is often confusing, inconsistent, and hard to understand (Alexander, 1983; Blain, 1970; Parsons & Mayhew, 1982; Savage, 1981). This has resulted in many critiques on supposedly Parsons' theory which are actually not critiques but corroborations. One of Parsons' former students, Mayhew, remarks about this:

> *"Despite the universal recognition of [Parsons] influence, his thought is not well understood. Perhaps we should not be overly surprised at this paradox, for his theories are often recondite, and many readers find his style opaque. I think there is a more substantial explanation of this paradox. It is precisely because Parsons has been so influential that he is so little understood. His work has been made to stand for orthodoxy. Hence, he is used as a straw man who is purported to assert one or another easily rebuttable proposition or simplistic theoretical stance, whereupon the heroic foe of orthodoxy demonstrates the absurdity of the 'Parsonian' view and emerges as a victorious champion of an alternative, novel, and embattled position. Such polemics are unlikely to produce a rounded perspective on the supposed exemplar of orthodoxy. Yet many sociologists are trained almost entirely from such secondary sources."* (Parsons & Mayhew, 1982: xiii)

An example of this is Giddens, who considers "[...] that a radical break has to be made with Parsonian theorems (Giddens, 1984: xxxvi)". Also he does "[...] not have much sympathy with those aspects of the writings of [Luhmann, Habermas, Bourricauld, Alexander and others] which are closely based on Parsons's ideas" (Giddens, 1984: xxxvi). In the meanwhile, we observe that Giddens adopts a large share of Parsons' (or Parsons' predecessors') ideas himself and adds to it. An example is that both Parsons and Giddens consider that the structure and behavior of a social system mutually affect one another.

At the risk of having appeared to be too much of a defendant of Parsons, we hope to have shown that Parsons' theory is richer, more nuanced, and therefore more valuable than often presented in its simplified misinterpretations. Hence, in addition to the indications for Parsons' theory that we received from the literature review (Chapter 2) and the empirical study (Chapter 3), we hope that this short evaluation of Parsons' theory omits doubts about its relevance for the current study. The next section explains how these ingredients are combined into a systemic KI model.

4.3 Method for Model Development

While there is an abundance of methods available for data gathering, there is relatively little written about methods for developing models. Rather, the literature discusses what capabilities are needed to develop and design models (or any object) and what are the characteristics of the model (or any object). Concerning capabilities, we find, for example, that a designer requires capabilities including creativity (Laurel, 2003), sensemaking (Weick, 1995), and combinative capabilities (Kogut & Zander, 1992). The only thing we can do here is hope that we possess these capabilities. Concerning the characteristics of a model, we find, for example, what are the characteristics of a theory (Whetten, 1989), a construction (Roth, 1982), or a model (Bertels & Nauta, 1969). We have specified the characteristics of a systemic model in Subsection 1.2.2.

In the literature on theory development we do find some principles for the development of a theory or model. We find there that theories should be developed by a constant interaction between theory and empirics. For example, Eisenhardt (1989) outlines a helpful process of theory building from case studies. In this process she provides guidelines for data collection, data analysis, and evaluation of the theory, much in line with what Glaser & Strauss (1967) call the constant comparison method and Dubin (1978) calls classification. The basic idea of theory development then is constant iteration between theory and data. Concerning the design of the theory itself, however, the literature on theory development often does not go further than stating that hypotheses should be developed based on the data. This statement does not help us very much in finding a method for the development of a systemic KI model.

A field in which the development of models is core is the field of design, and more specifically, the design of information systems (Hirschheim, Klein, & Lyytinen, 1996; Loucopoulos & Karakostas, 1995; Markus, Majchrzak, & Gasser, 2002; Pahl & Beitz, 1996). From this field we can extract the following principles:

1. Base your design on an analysis and specification of requirements.
2. Start from a general, conceptual design and continue to work on a detailed design.
3. Follow an iterative approach in which you test the model.

Concerning the first principle, we have collected requirements from the literature and practice in the previous chapters. Concerning the third principle, we will indeed follow an iterative approach, since we believe it is impossible to develop a systemic KI model at once. As it took Parsons a number of decades to develop the current version of his model of the social system, we believe it is unlikely that a systemic KI model can be fully developed within the boundaries of this study. Within this study, we make the first few iterations for the development of such a model, resulting in a model that has been confronted with a number of examples of practice (see Chapter 5). The development of a final model – if ever possible – goes far beyond this study. Future research will be needed in which further improvements are made (see Chapter 6).

Concerning the second principle – which is the only one concerning the actual design – we will indeed start from a general framework before we consider details. In a very general sense, we already have outlined the framework of the systemic KI model (Subsection 1.2.2). Also, we have started to specify some of the elements of this framework for the case of Parsons' theory (Subsection 4.2.1). In the remainder of this chapter we further fill this framework with details from respectively Parsons, the literature review, and the empirical study. The level of specificity increases since Parsons concerns social systems in general, the literature of Chapter 2 concerns the context of KI, and the empirics of Chapter 3 concerns KI in NPD of high-tech SMEs.

4.4 Applying Parsons to KI: Structural Characteristics

In the following subsections we step-by-step develop a systemic KI model. For each of the characteristics of a systemic KI model as they were discussed in Subsection 1.2.2, we summarize Parsons' view on it. Consequently, we invoke the results of Chapters 2 and 3, compare it with Parsons' theory and argue what systemic KI model can be developed from these sources. Wherever we refer to 'the literature' in this chapter, we refer to the literature reviewed in Chapter 2, unless remarked differently. Also, wherever we refer to 'the empirical results' we refer to the results of Chapter 3. The current section discusses the three structural characteristics of a systemic KI model. This is followed by a discussion of the behavioral characteristics (Section 4.5) and the control characteristics (Section 4.6).

4.4.1 Elements of a KI System

Parsons

The main unit of analysis of Parsons is the *act* or action, which he cryptically defines "[...] a process in the actor-situation system which has motivational significance to the individual actor, or, in the case of a collectivity, its component individuals" (Parsons, 1964: 4). Fundamental to the concept of an action is that "[...] it does not consist only of ad hoc 'responses' to particular situational 'stimuli' but that the actor develops a *system* of 'expectations' relative to the various objects of the situation" (Parsons, 1964: 5, original italics). According to Parsons, the 'actor-situation system' is the 'object world' which is composed of three types of objects: social, physical, and cultural objects.

Social objects are the actors of the system, "[...] which may in turn be any given other individual actor (alter), the actor who is taken as a point of reference himself (ego), or a collectivity [...]" (Parsons, 1964: 4). In Subsection 1.2.1 we have learned that in social systems, the *role* of an individual actor is important. This also is incorporated in Parsons' theory (Parsons, 1964). The concept of a role (and the related concept of a status) has been advanced by one of Parsons' students, Robert Merton (1968). Borrowing from Linton, Merton defines a status as a position in a social system occupied by individuals. A role, then, is the behavioral enactment of the expectations attributed to that position. Merton's main advancement was the introduction of the concept of a status-set and a role-set. A role-set is the "[...] complement of role relationships which persons have by virtue of occupying a particular social status" (Merton, 1968: 369). Correspondingly, a status-set is a complement of social statuses. In several works, Parsons pays a lot of attention to the nature and origin of roles. Initially, he defines roles by five concept pairs that he calls 'pattern variables': ascription vs. achievement, diffuseness vs. specificity, affectivity vs. affective neutrality, particularism vs. universalism, and collectivity vs. self (Parsons & Mayhew, 1982). Later on, he uses the four function paradigm described in Subsection 4.4.3 for this purpose (Alexander, 1983).

Physical objects are empirical entities that are means and conditions of the action. According to Parsons, "Physical objects [...] are always part of the situation of particular actors and of social systems" (Parsons & Smelser, 1956: 11). To define physical objects, Parsons borrows from economic theory. He distinguishes the three traditional factors of production: land, labor, and capital. Since "This whole subject has been so fully treated in the literature of economics that it need not detain us further here" (Parsons, 1964: 120), Parsons hardly elaborates on it.

Cultural objects are "[...] symbolic elements of the cultural tradition, ideas or beliefs, expressive symbolic elements or value patterns so far as they are treated as situational objects by ego and are not 'internalized' as constitutive elements of the structure of his personality"

(Parsons, 1964: 4). According to Parsons, cultural objects are the fourth production factor, which is congruent with, for example, Drucker's (1992) distinction between four production factors. While mostly, Parsons uses the term cultural objects, he sometimes refers to it as 'information' (e.g. Parsons & Smelser, 1956: 11) or 'knowledge' (e.g. Parsons, 1964). Although Parsons remains somewhat vague about the nature of cultural objects, or knowledge (Giddens, 1984), it can be seen that he recognizes different types. With his addition that cultural objects are different from symbolic elements internalized by actors, he seems to recognize that actors also possess symbolic elements. Similarly, he attributes symbolic elements to acts and physical objects as well (Parsons, 1964). A nice illustration of how Parsons distinguishes the various system elements to which 'symbolic elements' – or knowledge – are attributed is the following quote: "[...] specialized technical knowledge can be acquired only through labor, and often through access to other special facilities as well, such as the services of teachers and various types of equipment, e.g., books" (Parsons, 1964: 120). In this quote we recognize activities (labor), actors (teachers), and physical objects (equipment) as carriers of knowledge. Furthermore, Parsons seems to recognize that physical objects like books are different from other physical objects: "But many of the most important objects in which there are rights of possession are not physical at all, but may be cultural objects, e.g., the 'book' an author has written" (ibid: 119). Finally, Parsons also stresses that knowledge can reside in "[...] institutionalized patterns of the social system" (ibid: 89).

Discussion

When we compare the type of system elements that are distinguished in the literature with the types that Parsons distinguishes, there is a large amount of overlap and congruency. Naturally, the literature is more specific than Parsons. However, both distinguish actors (social objects), technology (physical objects), knowledge (cultural objects), and activities (acts) as elements constituting a system. Also, both the literature and Parsons recognize that knowledge can reside in actors, technology, activities, and combinations of these. Even the distinction between information technologies and non-information technologies is implicitly made by Parsons in his remark that for some objects the cultural aspect is more important than the physical aspect. Given this similarity in system elements that are distinguished by Parsons and by the KI literature, we believe that a systemic KI model should include the elements as they were distinguished before.

Despite of these similarities, there are differences as well. Firstly, while Parsons considers the role of knowledge in a social system as a whole, we focus on the KI system as an aspectsystem. Thus, while, for Parsons, knowledge is *one* element of the social system, in this study we are interested in knowledge as an aspect of *all* elements of a social system. This implies that our focus is different from Parsons' focus. However, as we have seen in the discussion above, this does not mean that the system elements are different. Hence, we believe that in a systemic KI model, we should adopt the shared view on system elements that emerges from Parsons and the literature.

Secondly, the literature pays more attention to information technologies as technologies of particular importance for KI. While Parsons does highlight that for some objects the physical aspect is more important and for other objects the cultural aspect, he does not make an explicit distinction between the two. As argued in Subsection 2.3.1, we believe that for a systemic KI model the difference is important. Since Parsons' work concerns the social system as a whole and our work focuses, like the KI literature, specifically on the KI aspect, we will include this distinction in the systemic KI model.

A third difference is the way roles are discussed in the literature and by Parsons. Parsons provides a complex theory of the nature and origin of roles (i.e. using both the five pattern variables described above which are sometimes even further differentiated, and the four functions described in Subsection 4.4.3). The literature also provides a complex of roles of actors in relation to the system they operate in and in relation to other systems. We believe a systemic KI model will become too complex when this complexity is incorporated. Also, we believe we do not need this full complexity. We are interested in those roles that are taken with respect to the KI system, not in other roles. The literature has provided us with three types of such roles (internal to the system, in relation to the environment, and in the relation between controlling organ and target system). Since these are better adjusted to the particular context of KI than the roles Parsons distinguishes, we will adopt them in the systemic KI model.

Finally, concerning the activities included in the model, Parsons discusses them at the most general level. At this level, they include probably all possible activities. On the other hand, our focus, and the focus of the reviewed literature, was on a substantially more limited and specific set of activities: KI activities. Concerning the character of activities, we accept Parsons' argument that activities are driven by 'expectations' or 'motivational significance' and are not ad hoc responses to particular stimuli. However, considering that a *KI* system consists of *KI* activities, we will adopt the activities that are mentioned in the literature in the systemic KI model. How this exactly is done, will be discussed in Subsection 4.5.1, where we discuss the patterning of KI activities.

The Elements of a Systemic KI Model

From the discussion above it can be concluded that no major changes have to be made to the view on KI system elements that has been developed in Chapters 1 and 2. In Chapter 1, Figure 1.2 illustrated our initial view on system elements. Below, we have adapted this figure according to the results of our analyses so far (Figure 4.1).

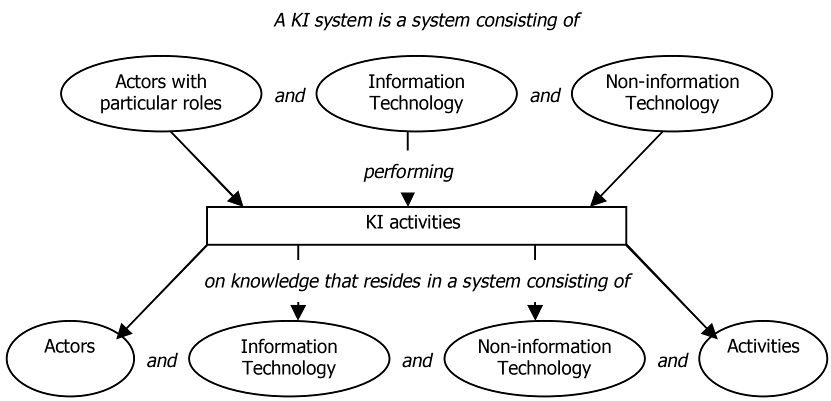


Figure 4.1 The elements of a KI system

Concerning the roles of actors, the systemic KI model should distinguish the following roles (see Subsection 2.3.1):

- In relation to the KI system: representative, professional, and specialist.
- In relation to the environment of the KI system: shared work producers, shared work practitioners, expert-seeking novice, and secondary knowledge miner.
- In relation to the controlling organ of the KI system: controlling organ, and target system.

Since neither Parsons nor the literature provides reasons to further differentiate the other elements, we will not further differentiate them at this point. However, Subsection 4.5.1 will further consider the types of KI activities to be included in the systemic KI model. In Chapter 5 we will evaluate whether each of these elements appears in the KI practice of new product development in high-tech SMEs (Subsection 5.4.1) and how it can help managers in practice to consider these elements of a KI system (Subsection 5.5.1).

4.4.2 Boundaries of a KI System

Parsons

In his definitions of a social system (see Subsection 4.2.1), Parsons provides information on the boundaries of the social system. This concerns the following elements of the definitions:

- A social system is *different* from its environment. This means that there is a theoretically and empirically significant difference between structures and behavior internal to the system and those external to it. One important aspect on which a system is different from its environment concerns its function towards the structures and processes contribute.
- A social system is *in some respect more stable* than its environment. This implies that the boundaries of the system can be established by determining a certain level of stability and separating those parts that meet this level from those parts that do not meet this level. Also this implies that the boundaries of a system depend on the aspect under study. For example, the boundaries of a KI aspect system can be different to that of a financial aspect system.
- A social system has a system of culturally structured and *shared symbols*. This implies that actors within the system have a shared language. This language might be different from the language outside the system.
- A social system is an *open system*. It draws resources from its environment, it is interdependent with it, and it interpenetrates with it. This implies that the boundaries of the system are permeable.
- A social system *maintains* a pattern of organization and functioning. This implies that at least part of the control of the system is included within the boundaries of the system and that part of the activities in the system aim at the maintenance of the system boundary.

Additionally, though not in the definitions, we find that system boundaries are *subject to change*. The boundaries of a system are stable only in a given timeslot and for a given aspect (Parsons, 1977: 103).

Discussion

In Subsection 2.3.2 we have discussed three aspects of system boundaries: their location, their character, and their origin. Each of these is discussed here as well. When we consider the location of system boundaries, the literature considered boundaries at the level of teams, departments, organizations, dyads of organizations, networks, and societies. While the literature thus already shows a variety of options to locate system boundaries, Parsons' work suggests an unlimited variety of options. While also Parsons distinguish the level of teams, organizations, institutions, and society (see Subsection 4.4.3), one of his main arguments is that the idea of a social system is applicable to any social phenomenon. Hence, with this respect, Parsons' work does not help us in establishing the location of the boundaries of a KI system. In Subsection 2.3.3 it was remarked that, within this study, the focus will not be on KI systems at the societal level. Concerning the location of the boundaries of a KI system, we can still not further specify the level at which we will set the boundaries. However, we can move on to compare the character and origin of system boundaries as they are discussed by Parsons and in the KI literature.

When considering the character of system boundaries; a similarity between the literature, the empirical study, and Parsons is that the system under study is (mostly) considered to be an open system that interacts with its environment. This implies that the boundaries of a KI system are permeable and thus, that a systemic KI model should consider system boundaries as permeable. With respect to the stability of system boundaries, there is a striking difference between Parsons and the literature. While Parsons extensively discusses the change of system boundaries (see Subsection 4.6.2 for a more extensive discussion on change), most of the literature considers system boundaries to be stable, or even fixed. Considering Parsons' remark that system boundaries are stable for a given timeslot, this difference seems not surprising: the literature mostly focuses on a certain timeslot. From this we can take that it depends on the user's objective whether a systemic KI model should have stable or changing system boundaries. However, since a model with changing system boundaries can easily be reduced to a model with stable boundaries and not the other way around, we suggest that a systemic KI model should consider system boundaries as subject to change.

Concerning the origin of boundaries there also are striking differences between the literature, the empirical study, and Parsons. In the literature, we have seen four types of origins: formal organizational boundaries, common physical environment, common interest or knowledge, and common activities, of which the first is highly dominant. Parsons distinguishes similar types of origins, but his main argument is that boundaries are based on the difference between a system and its environment on the aspect under study. This implies that system boundaries cannot be set in advance without considering the aspect under study. It is striking that the dominant way of defining system boundaries – by the formal organizational boundaries – just does this. These boundaries can be relevant for KI; however, they are not automatically. In the preliminary interviews of the empirical study we have noticed that system boundaries seemed to extend the single firm: the SMEs had long-term partnerships with other (parts of) organizations with which they exchanged knowledge on a regular basis. These other (parts of) organizations could be considered as part of the same KI system. On the other hand, in these interviews, KI did not always involve the SME in its entirety. For example, an SME might produce two completely different products where hardly any exchange of knowledge takes place between the departments producing them. Hence, these departments could be part of two different KI systems rather than of one single KI system.

The Boundaries of a Systemic KI Model

Given the preceding discussion on system boundaries, we believe that a systemic KI model should not automatically include organizational boundaries as system boundaries. Rather, systems theory suggests that such a model should place system boundaries where there is a theoretical and empirical difference in KI structures and processes between the system and its environment. This is depicted in Figure 4.2.

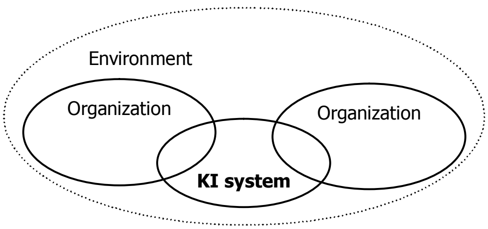


Figure 4.2 A KI system in relation to a formal organization and its environment

In Chapter 5 we will evaluate whether this conceptualization of the boundaries of a KI system is consistent with practice (Subsection 5.4.2) and whether it is useful for KI managers in practice to consider system boundaries in this way (Subsection 5.5.2).

4.4.3 Internal Structure of a KI System

Parsons

An important element of (social) systems theory is the nested nature of systems, suggesting that, at any given level, a system is part of a supersystem and decomposed into a number of subsystems. Parsons remarks about this “A complex social system consists of a network of interdependent and interpenetrating subsystems, each of which, seen at the appropriate level of reference, is a social system in its own right, subject to all the functional exigencies of any such system relative to its institutionalized culture and situation and possessing all the essential structural components, organized on the appropriate levels of differentiation and specification” (Parsons, 1961: 44). In Subsection 2.3.3, we distinguished four aspects of the structure of a KI system: levels of aggregation, subsystems according to system functions, subsystems according to knowledge functions, and control. Below we will present Parsons’ view on these four aspects. Because Parsons discusses the levels of aggregation and control simultaneously, we do so as well, after the discussion on functional subsystems.

System Functions

Parsons has spent a considerable part of his work on the decomposition of systems into four functionally differentiated subsystems. In this study, we have called these four functions the system functions (SFs). The four functions concern their contribution/effect for the system of which they are part. From his major work, 'The social system', until his later works, Parsons developed this notion of function extensively. Despite of the major influences and controversies of this notion (see e.g., Blain, 1970; Blain, 1971), the basic idea is a simple two by two matrix, which is depicted in Table 4.1. In order to explain the, what is now called, 'four-function-paradigm', Parsons discerns two orthogonal dimensions, which, according to him, are the two major axes that comprise four functions fundamental to any social system (Parsons, 1959).

The first of the two dimensions is the external-internal dichotomy. Internal functions concern relations between elements internal to the system; external functions refer to the relations between the system and its environment. The two external functions tend to "specialize with reference to the mediation of relations between the system and the situation external to it" (Parsons, 1959: 5). The two internal functions concern the units within the system, in particular the maintenance of their stability, and their integrative adjustments.

The second dimension concerns the distinction between instrumental and consummatory functions. According to Parsons, this dimension "is central to what Durkheim called the 'division of labor', through which parts are differentiated and concomitantly integrated through 'organic solidarity'. It is analogous to the differentiation between means and ends in terms of action as such" (Parsons, 1959: 6). Instrumental functions are those functions that build up and store resources; consummatory functions are those functions that consume and mobilize resources for actual performance. Other dichotomies that have been used to characterize the second dimension are indirect/direct, accumulative/consummatory, and flexibility/control (e.g. Quinn & Rohrbaugh, 1983).

Table 4.1 Four functions of social systems (adapted from Parsons, 1959)

	Instrumental (means)	Consummatory (ends)
External	**A:** Adaptive Function	**G:** Goal-Attainment Function
Internal	**L:** Latent Pattern-Maintenance Function	**I:** Integrative Function

Throughout his work, Parsons argues that the four functions that are comprised by the two dimensions are fundamental to the existence and survival of all social systems. The four functions can now be summarized as follows:

Adaptation (A): "Adaptation is external in the sense that it involves relating the system to an environment and instrumental in the sense that it involves, not the actual pursuit of particular environmental goals, but the development of generalized means for pursuing a variety of future goals and for meeting a variety of environmental conditions as they change over time [...]. Systems increase their adaptive capacities by developing generalized mobile facilities that are uncommitted to any particular use" (Parsons & Mayhew, 1982: 25). Key words are: economic system, receptivity, generalized, utility.

Goal attainment (G): “Goal attainment is [...] external in that it refers to achieving ends in relation to the environment, and consummatory in that it involves not the development of generalized instrumental resources but organization for the effective pursuit of particular system goals [...]. Social systems are well equipped for goal attainment when they have an organized capacity to control performances so as to bring them to bear on collective goals” (ibid: 25). Key words are: political system, effectiveness, specific, productivity.

Integration (I): “Integration requires relating the constituent units of a system to each other. Integration is a consummatory function in the sense that it involves, not the development of general facilities and resources for stability, but confrontation and solution of specific coordinative problems. Integration may be defined as the prevention of mutual interference of the units of a system with each other. In social systems, such interference may arise from conflict, from the breakdown of mutual expectations, or from a lack of complementarity of performances” (ibid: 26). Key words are: societal community, coordination, specific, mutual adjustment.

Pattern maintenance (L): “The principal resource for integration of the units within a system is consistency in the basic pattern of their relations. Hence, a system must have means of establishing and sustaining a stable structure” (ibid: 26). “Latent pattern maintenance is a defining and controlling, informational component of a social system rather than an operating component [...] pattern maintenance systems serve to define action, whereas the other three are aspects of ongoing action” (ibid. :27). Key words are: fiduciary system, stability, general, continuity.

Knowledge Functions

A second type of functions that we discern, are the KFs, or more generally, the resource functions. These functions concern the effect on the resource on which they operate. Although Parsons remains rather silent about these functions and considers them to be part of the technical system rather than the social system, in some of his works he explicitly refers to them. Borrowing from economic theory, Parsons discerns the generation, allocation, and utilization of resources (Parsons, 1961). In this distinction, resources are generated in one (sub)system, allocated to another (sub)system, and utilized by that other (sub)system. Since these functions can apply to all types of objects, and since Parsons categorizes knowledge as a cultural object, these three functions can be considered as KFs. Since Parsons hardly elaborates on these functions, we will not further specify Parsons’ view on these functions.

Aggregation Levels and Control

To explain the idea of system levels, Parsons uses the notion of a ‘structural hierarchy’ of systems in which he discerns four system levels. Individuals being the elements of which social systems consists, the lowest level is the *primary or technical level* for which “[t]he crucial point is the involvement of individuals with one another in cooperative activities which involve physical presence, at least part of the time, and direct cooperation in physical manipulations of the environment [...]” (Parsons, 1959: 10). The second level is the *managerial level*, which “[...] is the primary field to which the discussions of ‘formal organization’ and of ‘bureaucracy’ have had reference” (Parsons, 1959: 12). The role of this level is to provide systems at the primary level with the necessary input (‘material, equipment, and personnel’), to govern their output (by deciding 'what and how much to produce and on what terms it be made available to recipients'), to support them with services, and to exercise control. Control, in this latter sense, should be interpreted as correcting the inclinations of systems at the primary level to deviate from the fulfillment of their function in the larger system (Parsons, 1964: 206). The third (*institutional*) and fourth (*societal*) level perform similar roles towards their respective subsystems. While the role of the managerial level is to give the lower level specific guidance on what to do, the institutional level defines broad limits of what the lower levels "[...] may legitimately do and give them relatively broad community support in doing it" (Parsons, 1959: 14). Examples at the institutional level are the board of directors or trustees in a large organization, or associations and branch organizations in networks of organizations. At the highest level, the societal level, we find governments with supervisory, regulative, and supportive functions.

As we have seen in Subsection 1.2.1, in systems theory, the term hierarchy is used to refer to levels of aggregation rather than levels of control. When we consider Parsons' structural hierarchy, we believe that Parsons does not explicitly make the distinction between the two. On the one hand, he seems to refer to aggregation levels, for example, when he refers to them as groups, organizations, and societies. On the other hand, the relation between the levels is very similar to the relation between a controlling organ (CO) and a target system (TS). Parsons explicitly adds that "the scheme must not be simply dichotomized into controlling and being controlled" (1959: 16). As seen in Subsection 1.2.1, this is exactly how De Leeuw's has conceptualized control as well. Hence, although Parsons does not explicitly distinguish between levels of aggregation and levels of control, we believe Parsons' view on system levels is congruent with this distinction. Another congruency is that both De Leeuw and Parsons argue that a CO is not necessarily a concrete different system than a TS. Parsons' (1959) puts is as follows: "In the simplest cases, these need not involve distinct organizations at either role or collectivity levels, but, with general increase in level of differentiation, [...] there is a strong tendency to develop differentiated roles and collectivity structures which specialize at this level and which are not identical with the technically operative systems" (Parsons, 1959: 11). In conclusion, we believe we can summarize Parsons' view on system levels by stating that he distinguishes four levels of aggregation (group, organizations, institutions, and societies) which all have their own COs[7] and which all are differentiated into the four functional subsystems.

Parsons (1961) also touches upon system levels in relation to the three KFs but does not elaborate on it. He refers to system levels when he remarks that, within the utilization function, there is again an allocative function that allocates a resource "[...] to the collectivity, to the role, and to the task. The function of the collectivity is to define what is to be done; that of allocation to role, to define who is to do it; and that of the task level, how it is to be done" (Parsons, 1961: 64). Again, since Parsons hardly discusses the generation, allocation, and utilization functions, we will not further specify Parsons' view on them.

[7] Parsons adds to this that the social system is only one of four subsystems of the 'general action system'. The three other systems are the cultural system, the psychological system, and the behavioral-organic system. To reduce the complexity of this study, we have excluded these three other systems from all our discussions.

Discussion

As we have argued in Chapters 2 and 3, the literature and the empirical study showed similar divisions of a KI system into subsystems as Parsons, both with respect to the four SFs and the three KFs. Although neither the literature nor the empirical study showed this conclusively, the fact that both pointed in the same direction and that this direction concerns an established systems theory makes that we believe a systemic KI model should include the four SFs and the three KFs as discussed above and in Subsections 2.3.3 and 2.4.1. With the additions made in this subsection we now have a further theoretical background for the various functions that were distinguished earlier.

Also concerning levels of aggregation and control there seems to be a lot of agreement between the literature and Parsons. Besides the individual level, both consider the levels of groups (technical level) and organizations (managerial level). On higher system levels there appear some differences. For example, where the literature speaks of the interorganizational level and the level of the superstructure (i.e. Wijnhoven, 1999), Parsons speaks of the institutional level and the societal level. As we have excluded these higher levels from our analyses, we will not further elaborate on them.

Despite of these differences in focus, we believe the literature and Parsons also largely agree on the definition of aggregation levels and control. The similarity appears when we consider how KI systems at the technical and managerial levels are controlled. From Kim (1993) and Crossan, Lane, & White (1999) we take that groups are coordinated by shared mental models. Weick (1969) adds to this that groups are formed by shared means and/or shared ends. This is in line with Parsons description of a group (system at the technical level) where individuals directly cooperate with each other towards some common end. Also at the organizational level (the managerial level) we find these similarities. Where Kim and Crossan, Lane & White mention mechanisms like routinized actions and organizational mechanisms, rules, procedures, and diagnostic systems, Parsons mentions control, supervision, governing of input and output. These are to a large extent similar.

The Internal Structure of a Systemic KI Model

Considering the agreement between the literature, the empirical study, and Parsons' theory we suggest that a systemic KI model should take into account four SFs (adaptation, goal attainment, integration, and pattern maintenance) and three KFs (identification, acquisition, and utilization of knowledge). Moreover, we suggest that a systemic KI model should contain two system levels: the level of groups (primary or technical level) and the level of organizations (managerial level). Additionally, at each of these two levels, there should be made a distinction between a controlling organ and a target system.

In Chapter 1, Figure 1.1 presented the internal structure of a KI system in an abstract way. Below we have included an adapted version of this figure. Figure 4.3 shows a KI system at the organizational level decomposed according to system functions into four KI subsystems. The figure also shows that both the system at the organizational level, and the systems at the group level are controlled by their own controlling organ. As we have argued in Chapter 1, the CO at the level of the KI system is the targeted user of the outcome of this study.

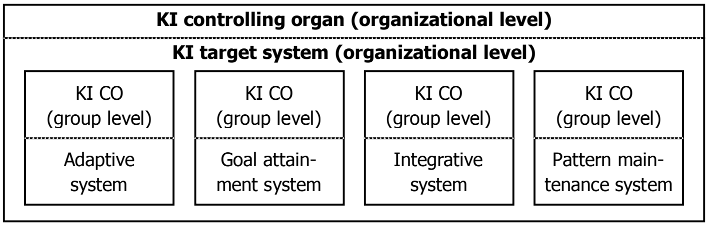


Figure 4.3 The internal structure of a KI system

Figure 4.3 presents three of the four aspects of the internal structure of a KI system that were discussed: levels of aggregation, SFs, and control. It does, however, not present the three KFs. In Chapter 3 we have seen that KFs do not seem to instantiate in patterns of KI activities. Because the structure of a KI system consists by the patterning of KI activities – and not by some physical structure – this means that there are no subsystems specialized in a particular KF. Hence, it is proposed here that the internal structure of a KI system is not differentiated into KFs. As also argued in Chapter 3, this does not mean that KFs are superfluous: they still need to be performed. As we have seen above and in Chapter 2, KFs appeared at both the system level (identification, acquisition, and utilization of knowledge from the environment of the system) and at the subsystem level (identification, acquisition, and utilization of knowledge from other subsystems). When we combine this with the structure of a KI system that is presented in Figure 4.3, we propose that a systemic KI model should consider that the three KFs are both performed at the system level (the organizational level) and the subsystem level (the group level). In Chapter 5 we will evaluate whether this conceptualization of the internal structure of a KI system corresponds with what we find in the practice of NPD in high-tech SMEs (Subsection 5.4.3) and whether this conceptualization seems useful for managers' KI problem solving (Subsection 5.5.3).

4.5 Applying Parsons to KI: Behavioral Characteristics

With the structural elements described in Section 4.4 we can create a static picture of a KI system. However, since social systems are dynamic systems, we also have to look at its behavioral characteristics. We can distinguish the following two characteristics: differentiated and patterned KI activities and interchange between systems.

4.5.1 Differentiated and Patterned KI Activities

Parsons

In Parsons' work, patterns of activities are a 'factual order' of these activities (Alexander, 1983). Hence, patterns refer to empirical clusters of related activities, rather than theoretically distinct categories of activities. Initially, Parsons used a number of 'pattern variables' for the patterning of elements of the system, including activities. Later on, Parsons turned to the four SFs for the patterning. Hence, within Parsons' theory, at any level of analysis, activities are supposed to cluster around one of the four SFs. This does not imply that the contribution of concrete activities is limited to one function. Just as concrete (empirical) systems, concrete (empirical) activities can contribute to more than one function. It is however supposed that in a developed system, activities specialize and thus will contribute more to one function than to other functions.

Since Parsons developed a general theory of action and the particular activities depend on the empirical field under study, Parsons does not provide us guidelines as to what type of KI activities pattern around which function. However, the theoretical background of the four functions (see Subsection 4.4.3) provides a helpful means to propose a patterning of KI activities.

Discussion

In Chapter 2 it was argued that KI activities can pattern according to SFs and according to KFs. Subsequently, we have seen in Chapter 3 that, in practice, KI activities seem to pattern according to SFs and not according to KFs. Hence, although KFs still are important *categories* of KI activities, they do not comprise *patterns* of KI activities. Therefore, we leave the KFs out of further consideration in this subsection. However, in our evaluation of the systemic KI model in Chapter 5, we will come back to the relevance of distinguishing them.

In the reviewed literature we have found two publications explicitly hypothesizing a patterning of activities around the 4SF model (see Subsection 2.4.1). The first is Moorman (1995) who hypothesized that the four functions emphasizes or de-emphasizes one or more of the processes of information acquisition, information transmission, conceptual information utilization, instrumental information utilization. However, as she failed to find empirical support for her hypotheses – which, as argued in Subsection 2.4.1, was not surprising – Moorman's work does not help us much further in establishing patterns of KI activities. The second publication patterning activities around the four SFs is Stein & Zwass (1995). Stein & Zwass hypothesize for each of the four functions of their model a number of activities to be performed by the concerning subsystem (also see Subsection 2.4.1):

- *Adaptive function:* boundary spanning activities to recognize, capture, organize, and distribute knowledge about the environment to the appropriate organizational actors.
- *Goal attainment function:* helping the organizational actors frame and identify goal states, store goal states, formulate strategies for achieving goal states, evaluate progress in the direction of goal states, suggest alternatives based on the evaluations, update goal states based on new information, and store annotated histories.
- *Integrative function:* sharing and integration of memory over time and space.
- *Pattern maintenance function:* containing the work history of individuals, with emphasis on project descriptions, capabilities, skills, and aspirations; support the preservation of organizational protocols and the values implicit in them.

Although Stein & Zwass did not strive for empirical validation in their paper, they remain rather close to the theoretical background of the 4SF model. Hence, we believe their patterning of activities is a useful input for the pattering of KI activities in a systemic KI model.

In addition to the literature, Chapter 3 has provided empirical indications for the patterning of KI activities onto the four SFs. From the analyses of that chapter, the following patterns emerged:

- *Adaptive function ('passive search'):* 'We come across knowledge without really looking for it' and 'Another organization presents knowledge unasked'.
- *Goal attainment function ('goal attainment'):* 'We intentionally search for knowledge', 'We receive documents and files from a source', 'We analyze products from a source', 'We attend a course given by a source', and 'We use it for the goal we acquired it for'.
- *Integrative function ('integration'):* 'We use it for other goals than we acquired it for', 'We store it for potential later use', 'We disseminate it to everybody concerned', and 'We make sure that we have similar knowledge internally available next time'.
- *Pattern maintenance function ('cooperation')*: 'We hire or employ persons from a source', 'We develop a product together with a source', and 'We outsource a problem to a source'.

Since the similarities and differences between these two attempts to pattern KI activities to Parsons' four functions were already discussed in Subsection 3.7.2, we will not repeat this discussion at this place. Rather, we turn directly to the discussion as to how patterns of KI activities should be included in a systemic KI model.

The Differentiated and Patterned KI Activities of a Systemic KI Model

Based on the theoretical input from Parsons and Stein & Zwass and the empirical input from the current study we can now translate the four SFs to the KI context and propose the kind of KI activities that contribute to a certain function. The following four types of KI functions are proposed:

1. *Adaptive KI:* the ability of the system to be receptive to changes in or introduced by external sources of knowledge. This type of KI function primarily focuses on openness and receptivity and tries to build up a general body of knowledge that can be used for multiple purposes. An example of this type of KI function is undirected environmental scanning in which an organization is exposed to information without having a specific purpose in mind with the possible exception of exploration (Aguilar, 1967; Choo, 2002; Daft & Weick, 1984).
2. *Goal attainment KI:* the ability of the system to set and achieve goals by identifying, acquiring, and utilizing knowledge from external sources. This type of KI function primarily focuses on productivity and efficiency. An example of this type of KI function is that of information seeking. Most information seeking models can be summarized as follows: for some goal an information need arises, which leads to someone, successfully or unsuccessfully, searching for information and reaching the goal (Case, 2002; Ellis & Haugan, 1997; Wilson, 1999).
3. *Integrative KI:* the ability of the system to develop into a coherent whole, by dissemination and integration of external knowledge in the system. This type of KI function primarily focuses on coordination and mutual adjustments of knowledge. Typical examples of this type of KI function are organizational memory and knowledge management processes (Stein, 1995; Walsh & Ungson, 1991; Wijnhoven, 1998).
4. *Pattern maintenance KI:* the ability of the system to create and maintain a stable and close relationship between elements of the system. This type of KI function primarily focuses on the value and development of stable human relationships. An example of this type of KI function is collaborative research and development in which interorganizational

networks are created and maintained (Groen et al., 2002; Jassawalla & Sashittal, 1998; Ring & Van de Ven, 1994).

The reader may observe at least two remarkable things with respect to these four functions. Firstly, in the pattern maintenance function the relationship with other organizations is incorporated. This seems rather contradictory since this function aims at the internal stability of a system (see Subsection 4.4.3). However, it is less surprising when we consider that not the formal organizational boundaries are considered to be the boundaries of the system, but the network of (parts of) organizations that closely cooperate (see Subsection 4.4.2). Secondly, the integrative function as described above does not include the reuse or exploitation of knowledge, while the results of Chapter 3 did point in that direction. The reason is that – following Parsons' theory – the reuse of knowledge should not be considered as part of the integrative function itself, but as the interface between the integrative function and the goal attainment function: in this case the integrative function ensures that the knowledge is reusable for the goal attainment function. Thus, here we explicitly give priority to the theoretical background of the four functions at the expense of the empirical background. A further elaboration on the interfaces between the functions is postponed to the next subsection which discusses the interchange between (sub)systems.

Since the number of KI activities is virtually unlimited (see Appendix I), we believe it to be undesirable, if not impossible, to pattern them all into the four functions. Therefore, we have defined the four SFs rather than categorized KI activities according to them. With these definitions, one can decide for each particular situation to which SF a KI activity contributes most. Chapter 5 will evaluate whether the four patterns of KI activities indeed appear in practice (Subsection 5.4.4) and whether it is useful for KI problem solving to consider them as part of a systemic KI model (Subsection 5.5.4). In the same subsections, we also evaluate whether the three categories of KFs appear in practice and whether it is useful for KI problem solving to distinguish them.

4.5.2 Interchange in a KI System

Parsons

In Parsons' theory and that of his successors, such as Luhmann and Habermas, interchange between (sub)systems is crucial for the functioning of the system, in particular for its integration. For the (sub)systems themselves, the need for interchange means that they are dependent on other systems and are restricted in their freedom. For example, the adaptive function needs inputs from the three other functions, implying that it cannot 'idealistically' achieve its objectives (Alexander, 1983: 80-86). Parsons has conceptualized the interchange between systems as a 'double interchange'. In his theory, an interchange consists of, on the one hand, a transfer of 'real entities' from a source to a recipient and, on the other hand, a transfer of 'symbolic entities' in the opposite direction (Parsons & Mayhew, 1982). Parsons explains this as follows: "The first are the resources which, starting from outside the system, go through various phases as they pass through the system, and at certain points are used in the system's functioning. The second are the types of mechanisms which mediate these processes of generation and utilization of resources and regulate their rates of flow, direction of use, etc." (Parsons, 1961: 60). Parsons calls these mechanisms the generalized media. The interchange is double in that the resources and the generalized media can flow in two directions: from actor A to actor B and vice versa. Parsons uses the following example to explain the double interchange: "Members of the households exchange their labor for wages and, in turn, exchange their wages for the products of business enterprise" (Parsons & Mayhew, 1982: 32).

Concerning the resources that are interchanged, it is Parsons' conceptualization of knowledge that interests us. In Subsection 4.4.1, we have seen that in Parsons' conceptualization of knowledge we can find the same typology as we found in the literature: knowledge resides in actors, activities, information technologies, non-information technologies, and combinations of these. The transfer of these types of knowledge can be seen as one part of the double interchange between systems.

Concerning the generalized media of interchange, Parsons has put substantial effort in deducing them from the four system functions. This has resulted in four media, each attributed to a particular function:

1. money or inducement: offering rewards, attributed to adaptation
2. power or deterrence: applying negative sanctions, attributed to goal attainment
3. influence or persuasion: offering reasons, attributed to integration
4. value commitments: invoking existing commitments, attributed to pattern maintenance

It is important to repeat that also here, Parsons refers to abstract conceptual media rather than concrete empirical media. Hence, the term 'money', for example, refers to a broader set of rewards than to financial rewards only (Alexander, 1983).

An interesting addition that Parsons makes, is that he conceptualizes the interchange between the four functions as systems themselves. Hence, in addition to the four functional systems, he distinguishes six interchange systems (Parsons, 1977; Chernilo, 2002). Since it is the double interchange that forms the core of these interchange systems – and not the patterning of activities – these interchange systems are different from the four subsystems: while the four functional subsystems are responsible for how inputs are transformed into outputs, the six interchange systems are responsible for how inputs and outputs are interchanged.

In Subsection 1.2.1 it was argued that systems have their own controlling organs (COs). Although Parsons does not make this very explicit, the conceptualization of an interchange as a system suggests that interchanges also have their own COs. While the COs of the functional subsystems themselves control the patterns of activities within the functional subsystems, the COs of the interchange systems, then, control the interchange between two functional subsystems,. This is depicted in Figure 4.4.

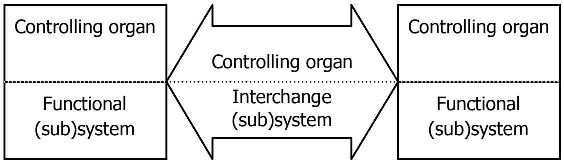


Figure 4.4 Interchange systems and their controlling organs

When we look at concrete systems, interchanges can be controlled by a separate CO. An example is a knowledge broker, or intermediary that controls how interchanges between a source and a recipient take place. However, in many cases it seems likely that the controlling function of an interchange system is performed by the same CO that controls the source or the recipient subsystem. This is best understood by an example. Suppose a high-tech SME wants to buy a journal article from a university library. In this case, both the high-tech SME and the university library have their own COs, which are responsible for their internal functioning. Additionally, the CO of the high-tech SME is controlling the interchange in that it wants to achieve a particular goal by exerting its influence on the university library: it wants to obtain knowledge (in the form of a journal article) in return for generalized media (in the form of money). In this case, the CO of the high-tech SME does not control the university library (i.e. the CO of the high-tech SME does not try to influence how the library will realize the output of a journal article), but it does control the interchange.

Discussion

While there seems to be agreement amongst influential sociologists (e.g. Parsons, Habermas, and Luhmann) that generalized media play an important role in the interchange between systems, there is hardly any agreement on what these generalized media are and what types exist. While Parsons attributes one generalized medium to each function, there seem to be substantial agreement that it is not possible and desirable to deduct the generalized media from the four functions (Alexander, 1983; Chernilo, 2002; Habermas, 1987; Johnson, 1973; Künzler, 1989; Luhmann, 1977). It is argued that the four generalized media are not the only ones and that they are not necessarily attributed to a particular function. For example, Luhmann adds truth and love as additional media (Luhmann, 1995) and Habermas adds law (Habermas, 1987), both without reference to the four-function paradigm.

In Subsection 2.4.2, we have seen that the KI literature distinguishes a variety of motivators to share knowledge. As argued there, these motivators can be considered as generalized media that are interchanged for knowledge. When we compare these motivators to the four generalized media of Parsons, we can find examples in the literature of each of the four media of Parsons. For example, we find examples of sharing knowledge for money (e.g. salary and revenue), power (e.g. power of others and obligation), influence (e.g. achievement and competence), and value commitments (e.g. moral obligation and commitment). However, as also Luhmann and Habermas have argued, these four seem to be not the only generalized media; or at least, the media as they appear from the literature are more differentiated than in only four categories. For example, while it is perhaps possible to categorize 'protecting the knowledge', 'prestige', and 'achievement' in Parsons' category of 'influence', the three are different. As presented in Table 2.4, 'protecting the knowledge' refers to safety, 'prestige' to esteem, and 'achievement' to self-actualization. Hence, we believe it would reduce the richness of the KI literature too much when we fully adopt Parsons' view concerning the generalized media.

The view of interchanges that has been discussed until here may suggest that interchange between KI (sub)systems) is a simple 'package transfer' of knowledge for other knowledge or for some generalized medium. As we have seen in Subsection 2.4.1, in the discussion of knowledge acquisition activities, this is however not the case. Knowledge transfer can require intensive cooperation between source and recipient. Given that interchanges in KI thus may require much time and effort, it seems to us that Parsons' idea to consider interchanges as systems themselves is a useful idea in the context of KI. Hence, we will adopt this view on interchanges in the systemic KI model.

In the discussions above and in Subsections 2.3.1 and 2.4.2 we have discussed several types of carriers of knowledge and several types of generalized media and we have argued that these are interchanged. Also, in Subsections 4.4.3 and 4.5.1 we have discussed the four functional subsystems in detail. As these four subsystems are comprised of different KI activities, their outcomes also are different; that is, they produce different types of knowledge. We assume that this difference lies not in the carriers of knowledge, but more in the function of knowledge. Based on the definitions of the four functions that were given in Subsection 4.5.1, we can now distinguish four types of knowledge. These four types are characterized in Table 4.2 by indicating for each function what knowledge it produces, how knowledge is considered, and which aspect of knowledge is stressed.

Table 4.2 Knowledge outputs from the four functional subsystems

	Instrumental	*Consummatory*
External	**Adaptive function** Produces generally applicable knowledge Knowledge as value Focus on usability of knowledge	**Goal attainment function** Produces applied knowledge Knowledge as production factor Focus on suitability of knowledge
Internal	**Pattern maintenance function** Produces durable knowledge Knowledge as memory Focus on longevity of knowledge	**Integrative function** Produces integrated knowledge Knowledge as a whole Focus on compatibility of knowledge

An example of an interchange is knowledge reuse. In terms of interchanges between the four types of KI functions, knowledge reuse is an example of an interchange by which knowledge that was integrated before is now used for goal attainment. Hence, knowledge from the integrative function is exchanged for some generalized medium from the goal attainment function.

Interchanges in a Systemic KI Model

From the discussions above and Subsection 2.4.2 we now have a rich picture of interchanges between KI (sub)systems. As argued above, we will include this rich picture in the systemic KI model. This implies that the systemic KI model should include the idea of a double interchange in which knowledge is exchanged for other knowledge or for generalized media. Given the variety in knowledge carriers, knowledge outputs, and generalized media, this means that the systemic KI model includes many possible instantiations of interchanges. As also argued above, we suggest that also the notion of interchange systems – and their COs – should be included in the systemic model. While Parsons has defined six interchange systems with their own types of resources and generalized media, we suggest that the systemic KI model should be more flexible. Rather than defining six interchange systems, the model will adopt the notions of interchange systems and double interchanges, and will allow for different instantiations of them. This is depicted in a simplified form in Figure 4.5, in which each of the pairs of arrows should be seen as interchange systems with their own CO.

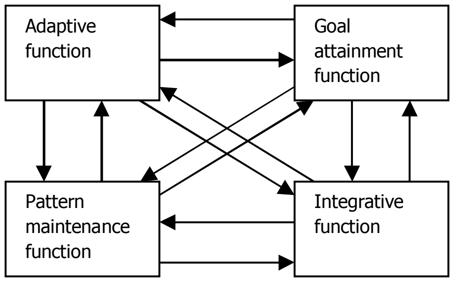


Figure 4.5 Interchanges between KI (sub)systems

In Chapter 5 it will be evaluated whether this conceptualization of interchanges between KI (sub)systems represents how interchanges take place in practice (Subsection 5.4.5) and whether this conceptualization is useful for KI problem solving (Subsection 5.5.5).

4.6 Applying Parsons to KI: Control Characteristics

The final type of characteristics of a systemic KI model is the control characteristics. We have identified two of these characteristics: goal-directedness and evolution of a KI system. Both are discussed below, respectively in Subsections 4.6.1 and 4.6.2.

4.6.1 Goal-Directedness of a KI System

Parsons

The importance of goal-directedness in a social system is clearly marked in Parsons' definition of a theory of action (of which social system theory is a specific type):

> *"By a theory of action is here meant any theory the empirical reference of which is to a concrete system which may be considered to be composed of the units here referred to as 'unit acts'. In a unit act there are identifiable as minimum characteristics the following: (1) an end, (2) a situation, analyzable in turn into (a) means and (b) conditions, and (3) at least one selective standard in terms of which the end is related to the situation. It is evident that these categories have meaning only in terms which include the subjective point of view, i.e., that of the actor. A theory which, like behaviorism, insists on treating human beings in terms which exclude this subjective aspect, is not a theory of action in the sense of this study"* (Parsons, 1937: 77-78).

This definition highlights mainly the goal-directedness of individuals and less that of the system. This seems surprising, since Parsons is often blamed for reducing the role of the individual actor to a functional element in the system (see Subsection 4.2.2). According to Parsons, his theory operates between these two extremes in what he calls a 'voluntaristic theory of action' (Parsons, 1961: 81). In a voluntaristic theory of action, actions are influenced by both normative and conditional elements. Normative elements are the subjective and individual elements that are stressed in the 'idealistic theory of action'. They consist of cognitive, affective, and teleological orientations of individuals (Parsons, as summarized by Wearne, 1989: 106). Conditional elements are the objective elements external to the individual that are stressed in the 'positivistic theory of action'. They stem from the function of the individual in the system. Dependent on the function, these goals are more specific (goal attainment and integration) or less specific (adaptation and pattern maintenance). The voluntary element means that, according to Parsons, individuals often choose to voluntarily conform to the conditions of the system in which they act. An alternative way in which Parsons has formulated this voluntarism is in his description of goals in organizations: "what from the point of view of the organization in question is a specified goal is, from the point of view of the larger system of which it is a differentiated part or subsystem, a specialized or differentiated function" (Parsons, 1956a: 66). This suggests that when we speak of goals of KI (sub)systems, these are similar to their functions. Hence, the goal of the KI adaptive function is to be receptive to influences from the environment, the goal of the KI goal-attainment function is to be productive, etc. As can be extracted from the discussion of Parsons' view on control (Subsection 4.4.3), a voluntaristic theory of action does not mean that actors always choose to conform to the expectations of the system: sometimes 'corrective actions' are needed to make actors act in line with the expectations of the system.

Goal-directed action does not imply that all the consequences of the action are known in advance. Hence, there is a difference in motives and objective consequences of actions (Merton, 1968: 60). Derived from Bernard, this idea was advanced by Merton in his distinction between manifest and latent functions "the first referring to those objective consequences for a specified unit [...] which contribute to its adjustment or adaptation and were so intended; the second referring to unintended and unrecognized consequences of the same order" (Merton, 1968: 63). Parsons adopted this notion (Parsons, 1977: 100).

Discussion

There are a number of similarities between the literature and Parsons. Firstly, the literature has identified cognitive, affective, and situational goals (see Subsection 2.5.1). These are similar to Parsons' cognitive, affective, and teleological goals. Another similarity is the recognition of different degrees of goal directedness. Both Parsons and the literature consider general goals (e.g. in the adaptation function) and specific goals (e.g. in the goal attainment function). There also is a lot of similarity in the assumption that conflicts in interest will be resolved and that goal formulation is an iterative process. For example, in the literature we see this in Taylor's (1968) idea of question-negotiation in information seeking: although source and recipient have different interests, Taylor assumes that, at the end, both are interested in a similar outcome: information is found. As discussed above, Parsons has similar assumptions. Another similarity is that both in the literature and in Parsons' theory there appear unintended consequences as outcomes of activities. Parsons (1977: 100) refers to Merton's concept of latent functions and in the literature we see this in the form of companies stumbling upon useful information they were not looking for (Aguilar, 1967). Also in the empirical study we have seen that companies sometimes find relevant information in this way. A final similarity is that both the literature and Parsons distinguish goals of different levels of abstraction. Both discern multiple system levels where at higher levels of aggregation, goals are of higher levels of abstraction than at lower levels of aggregation: at the highest level there are 'general values' and at the lowest levels there are 'norms governing specific actions' (Parsons, 1959: 8).

In addition to the similarities, there are differences between the literature on the one side and Parsons and the empirical study on the other side. In Subsection 2.3.3 it was mentioned that, in part of the literature, KI was treated as a goal in itself without further relation to other goals. We did not find this kind of goals in Parsons' theory and in the empirical study. Parsons only considers activities that have a – latent or manifest – function. In the preliminary interviews of the empirical study, it seemed that there is simply no time for performing KI activities for the sake of performing KI activities. Also, it seemed that people were mainly driven by situational/teleological goals rather than cognitive and affective goals. People seem to accept situations as uncertainty and sensemaking gaps. However, they seem to feel that the NPD problem they face should somehow be solved.

Goal-directedness in a Systemic KI Model

These considerations about goal-directedness lead us to suggest that in a systemic KI model goals should be included in each KI (sub)system at each system level. In a KI system, actors, subsystems, and supersystems strive for the achievement of their own goals. At a given system level this implies that the system itself has certain goals, that its supersystem has certain goals, that other systems within the supersystem have certain goals and that its subsystems and individual actors have certain goals. The KI system at that given level will have to interact with these other systems in order to formulate and achieve its goals. While striving for their goals, the (super/sub)systems produce unintended consequences that contribute to other goals. The relation between goals, KI activities, and intended and unintended outcomes is presented in Figure 4.6. It shows the mutual influence of two goal-activity-consequences sets. It shows how the consequences of one KI activity affect both other goals and the goal that was driving that action. The mechanism is applicable to all possible relations between (sub/super)systems. Also, the relationships are not strictly 1-to-1. Multiple goals can lead to a single KI activity, multiple KI activities can follow a single goal, single KI activities can have multiple consequences, and so on and so forth. When represented in the form of Figure 4.6, this would mean that at each of the nodes, a new circle could be added.

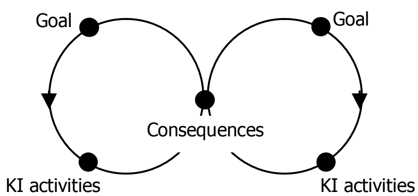


Figure 4.6 The relation between two goals, KI activities, and consequences in a KI system

In Chapter 5 we will evaluate whether the view on goal-directedness that is outlined in this subsection does reflect goal-directedness in practice (Subsection 5.4.6) and whether this conceptualization is useful for KI problem solving (Subsection 5.5.6).

4.6.2 KI System Evolution

Parsons

The final characteristic of a systemic KI model concerns the change of a KI system. Parsons considers change to be evolutionary rather than revolutionary or disruptive. This implies that systems change gradually in the course of time. Also, to Parsons, when systems change, they become more advanced – which is probably why Parsons uses the word evolution rather than change (Savage, 1981: 208). As systems become more advanced they become more differentiated (Parsons, 1977; Parsons & Mayhew, 1982). This implies that in the course of time, its subsystems become more specialized towards one of the four functions.

According to Parsons, there are both exogenous and endogenous sources of change. Exogenous sources concern changes in systems that are connected to the system in question; endogenous sources concern strains between subsystems of the focal system. When reacting to such sources of change, social systems have to balance between maintaining stability and adapting to the new situation. In terms of the four functions, the maintenance of stability can be considered part of the pattern maintenance function. The adaptation to the new situation cannot be attributed to a specific function. Namely, while two of the four functions concern the relation with external systems (adaptation and goal attainment), the other two functions concern the internal part of the system. Hence, if the system has to adapt (internally) to an external source of change, this requires at least an internal and an external function and their interaction. About the processes of change we have found no thoroughly developed concepts in Parsons' work, perhaps because "[...] a general theory of the processes of change of social systems is not possible in the present state of knowledge" (Parsons, 1964: 486). However, in a summary of Parsons' (e.g. 1977) view on social evolution, Mayhew (Parsons & Mayhew, 1982) and Savage (1981) discern four stages:

1. *Differentiation:* Systems differentiate because this enhances adaptive capacity, the capacity of a system to control the environment and to adjust to environmental variety and change. Hence, differentiation allows for higher levels of performance. This is the goal attainment function of change.
2. *Adaptive upgrading:* Equipping the units of the system with the capacity to achieve the new, higher levels of productive output. An example is training of employees. This is the adaptive function of change.
3. *Inclusion:* Reincorporating the specialized roles and groups that emerge in the preceding processes into the existing normative order. This is the integrative function of change.
4. *Value generalization:* The normative order must change to adjust to the new realities without leaving behind fundamental commitments on which the stability of the system depends. The structure of the system must be changed so that the system is able to comprehend and govern a wider variety. This is the pattern maintenance function of change.

In these four stages we see again Parsons' inclination to express everything in terms of the four functions. Also, we see that, according to Parsons, change is directed towards greater adaptive capacity of the system.

Discussion

A similarity between the literature, the empirical study, and Parsons is the focus on evolutionary rather than revolutionary change. A related similarity is that both the literature and Parsons base their notions of change on evolution theory. In both the learning models mentioned in Subsection 2.5.2 and in Parsons' theory mentioned above, we find reference to the notions of variation, selection, and retention that appear in Darwin's theory of biological evolution. Parsons' view on system evolution has been controversial, in particular his view that evolution is directed towards more adaptive systems (Savage, 1981). While Parsons' view of evolution is based on Darwin's evolution theory, the idea that systems become more adaptive cannot be found in this evolution theory (Hannan & Freeman, 1977; Hannan & Freeman, 1984; Savage, 1981). In addition to the fact that Parsons' view is thus inconsistent with Darwin's view, it also is not congruent with what we see in practice. Following Parsons' view would mean that advanced systems would be that adaptive that they would become independent of environmental conditions; that is, they would not need to evolve anymore, but this is not what we see in practice (Savage, 1981). When we look in the KI literature (see Subsection 2.5.2), we also do not find the idea that change, or learning, is always directed towards more adaptive systems. Given this lack of support of this part of Parsons' view of system evolution, we believe that a systemic KI model should not make the restriction that system evolution is always directed towards a more adaptive system. However, we do assume that change in a KI system is not random, but directed – at least in intention – towards improvement of the functioning of the system.

A difference between the KI literature and Parsons' theory is that the literature explicitly distinguishes single-loop and double-loop learning, while Parsons sees them as part of the same evolution process. As can be extracted from the four evolution stages discussed above, Parsons considers evolution to be a continuous process that starts with change in behavior and ends with change in structure. Since Argyris and Schön (1978) considered single-loop and double-loop learning also as two ends of a continuum rather than as two different types of learning, we believe that the KI literature and Parsons are congruent at this aspect of system evolution. Hence, we suggest that, although single-loop learning and double-loop learning are different, a systemic KI model should not stress the distinction between single-loop and double-loop learning, but should stress that they are part of the same evolution process.

A more important distinction that emerges from Parsons' theory is the distinction between the four functions that we have seen before. While the KI literature considers the evolution process in general, from Parsons' theory we can extract that within a KI system, each of the four functional subsystems can evolve. Hence, rather than discerning single-loop from double-loop learning, we suggest that a systemic KI model should discern four types of 'functional learning'. This means that the experiential learning cycle, as described by Kolb, can be applied to each of the four system functions and not only to a KI system as a whole. Moreover, in the KI literature we have seen that systems cannot only learn from their own experiences, but also of models and experiences of others. This suggests that the functional subsystems also can learn from each other. We therefore suggest that a systemic KI model should include a notion of 'inter-functional learning'.

A further difference between the KI literature and Parsons' theory is that the first explicitly distinguishes between the cognitive and the behavioral aspect of learning while Parsons does not seem to make this distinction. Since knowing that something should be changed is very different from actually changing it, we believe the distinction between the two aspects is relevant for a systemic KI model.[8] Also, the idea that systems can learn from models rather than only from concrete experiences (see Subsection 2.5.2) seems to highlight the importance of the distinction between the two aspects.

A final difference between the literature and Parsons is that a small part of the literature pays attention to the 'change of change' while we have not found this in Parsons' theory. With 'change of change' we refer to deutero learning, which is the 'learning of learning' (see Subsection 2.5.2). We assume that deutero learning can take place both at the level of a KI system and at the level of its functional subsystems.

Evolution in a Systemic KI Model

Both in the KI literature and in Parsons' theory, the notion of system evolution has received much attention. Considering the discussion above, we suggest that a systemic KI model should distinguish four types of functional learning and inter-functional learning, should distinguish between the cognitive and behavioral aspect of learning, and should recognize deutero learning. Figure 4.7 suggests how these notions are to be included in a systemic KI model. Perhaps it is useful to remind the reader at this point, that, since this subsection concerns the evolution of a KI system, learning refers to the learning of KI, not to learning in general.

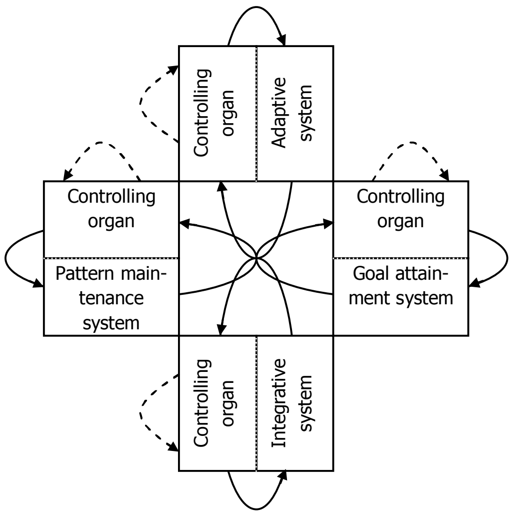


Figure 4.7 Learning in a systemic KI model

[8] By explicitly making this distinction, we touch upon Gidden's (1984) critique of Parsons that there is not enough attention to the 'knowledgeable actor' in Parsons' theory.

In Figure 4.7, functional learning is modeled by the loops between a functional subsystem and its controlling organ (the ellipses); inter-functional learning by arrows from one functional subsystem connecting to arrows to the controlling organ of another functional subsystem; and deutero learning by the dotted arrows. The arrows from the functional subsystems to the controlling organs represent the cognitive aspect of learning and the arrows from the controlling organs to the functional subsystems represent the behavioral aspect of learning.

4.7 Discussion and Conclusion

With the inclusion of the evolutionary aspect of a KI system, we have now discussed each of the seven characteristics of a systemic KI model. Hence, when can now go back to the research question that has guided this chapter, which read: '*What systemic KI model can be derived from the framing of the gathered material into Parsons' social system theory?*' The two subquestions were:

a. To what extent is Parsons' social system theory applicable to the KI context?
b. What systemic KI model can be derived from the framing of the gathered material into the applicable part of Parsons' social system theory?

In order to answer these research questions, this chapter started with a short summary of Parsons' theory and its critiques. Thereafter, this chapter has elaborated on those parts of Parsons' theory that relate to the seven characteristics of a systemic KI model that were defined in Subsection 1.2.2. Consequently, the results of Chapter 2 (literature review) and Chapter 3 (empirical study) were invoked to develop a systemic KI model using Parsons' theory as a framework.

With respect to the first subquestion, we have argued that some of the critiques to Parsons' theory are not fully justified or are not relevant to this study. With summarizing Parsons' theory and its critiques in Section 4.2, we have argued that Parsons' theory is relevant and useful to this study. Since Parsons' theory is vast and covers issues ranging from the role of universities, to economics and culture, it cannot be applied fully in a systemic KI model. Therefore, we have restricted the discussion of Parsons' theory by only discussing the general theory and excluding its application to the numerous sociological issues. Thus, we have assumed that Parsons' general theory is applicable to the KI context. The extent to which this theory is applicable to the KI context appears from the discussions in Sections 4.4 through 4.6. In these sections we extracted, from Parsons' theory, his view on each of the seven characteristics of systemic model. As appears in these sections, we do not fully adopt Parsons' theory here. For example, we leave the system levels of institutions and societies out of consideration and do not follow Parsons in his argument that system evolution is always directed towards more adaptive systems. Hence, in response to the first subquestion we argue that Parsons' general theory is to a large extent, but not fully, applicable to the KI context. For a more detailed answer to this subquestion, we refer to the corresponding sections in this chapter.

With respect to the second subquestion, each of the subsections of Sections 4.4 through 4.6 ended with a conclusion concerning how the respective characteristic should be included in a systemic KI model. We will not fully repeat these conclusions at this place. Rather, we will, as we did when summarizing Parsons' theory in Subsection 4.2.1, summarize the main ideas:

- A KI system consists of actors with particular roles, information technology, and non-information technology performing KI activities on knowledge that resides in a system consisting of actors, information technology, non-information technology, and activities (Subsection 4.4.1).
- A KI system has permeable and changing boundaries that can be different from the formal organizational boundaries in that a KI system can include parts of several organizations and exclude other parts of these organizations (Subsection 4.4.2).
- A KI system consists of two levels: an organizational level and a group level. At the group level, there are four functional subsystems responsible, respectively, for adaptation, goal attainment, integration, and pattern maintenance. A KI system and its subsystems each have their own controlling organs, of which the controlling organ of the KI system as a whole is the intended user of the systemic KI model (Subsection 4.4.3).
- The KI activities within a KI system are patterned into the four system functions. These patterns can be summarized as follows:
    - *Adaptive KI:* the ability of the system to be receptive to changes in or introduced by external sources of knowledge.
    - *Goal attainment KI:* the ability of the system to set and achieve goals by identifying, acquiring, and utilizing knowledge from external sources.
    - *Integrative KI:* the ability of the system to develop into a coherent whole, by dissemination and integration of external knowledge in the system.
    - *Pattern maintenance KI:* the ability of the system to create and maintain a stable and close relationship between elements of the system .

  KI activities also can be categorized into the three knowledge functions of identification, acquisition, and utilization. These knowledge functions are performed at the system level and at the level of its subsystems (Subsection 4.5.1).
- KI (sub)systems interchange knowledge for other knowledge or for generalized media. Since there are different type of knowledge, knowledge carriers, and generalized media, there is a variety in how interchanges instantiate. The interchanges are to be seen as systems in themselves, having their own controlling organ (Subsection 4.5.2).
- A KI system, its subsystems, and the individual actors that are part of them each try to achieve their own goals. The KI activities performed to achieve these goals lead to intended and unintended consequences. Goals, KI activities, and consequences mutually affect one another (Subsection 4.6.1).
- A KI system evolves towards a better functioning of the system by adjusting its behavior and structure. This evolvement takes place by four types of functional learning (i.e. for each system function), inter-functional learning, and deutero learning. Learning has both a cognitive and a behavioral aspect (Subsection 4.6.2).

The next chapter provides an assessment of the systemic KI model that was developed in this chapter by confronting the model with detailed examples of KI in practice. The main purpose of this assessment is a further improvement of the model in terms of the objectives that were set for it in Section 1.3.

CHAPTER 5: IMPROVEMENT OF THE SYSTEMIC KI MODEL

"Of course, the researcher does not approach reality as a tabula rasa. He must have a perspective that will help him see relevant data and abstract significant categories from his scrutiny of the data."

Glaser & Strauss (1967: 3).

"Broadly speaking, the preference for one theoretical model over another is a matter of consensus [...].Truth, insofar as a theoretical model is 'true', rests exactly on that slender base of expert consensus".

Dubin (1978: 13)

5.1 Introduction

Chapter 4 has presented a systemic KI model that is based on the outcomes of the literature review (Chapter 2), the outcomes of the empirical study (Chapter 3) and Parsons' social system theory. As such, that chapter concerned the second phase of this study: the design of the systemic KI model. The current chapter presents the third and final phase of this study: the evaluation of the systemic KI model against KI in the practice of new product development (NPD) in high-tech SMEs. The objective of this evaluation is not a full empirical test of the validity and reliability of the model. Rather, the evaluation aims at a further improvement of the model. The research question guiding this evaluation is: *What is the soundness and relevance of the developed systemic KI model and how should it be improved?* It is subdivided into the following two subquestions.

a. To what extent is the model sound and how can its soundness be improved?
b. To what extent is the model relevant for KI problem solving and how can its relevance be improved?

The first subquestion concerns the soundness of the model, which refers to the traditional scientific criteria including correctness, consistency, and precision. As will be argued in this chapter, it is not desirable to extensively test the soundness of the model empirically at this stage of the research. Rather, we will base our arguments on the previous chapters in answering this first subquestion. The second subquestion refers to relevance of the model to practice. As introduced in Subsection 1.2.2, relevance refers to the criteria of manageability, fit with the problem, and timeliness. In order to answer this second subquestion, the model of Chapter 4 is evaluated against examples of KI in the practice of NPD in high-tech SMEs. These examples will be used in two different ways. Concerning the manageability criterion, the examples will be used to evaluate whether the systemic KI model is manageable in its current form, or whether it should be simplified in order to make it better manageable. Concerning the fit with the problem criterion, the (simplified) model will be used to analyze a number of examples from practice in order to find out whether and how the model can help practitioners with KI problem solving. This evaluation is hypothetical since we do not use the KI model to intervene in practice but to analyze examples retrospectively. Finally, the model is evaluated against the criterion of timeliness. As will be argued in Section 5.6, this final evaluation will be based on arguments rather than empirical data.

The chapter is organized as follows: the next section (Section 5.2) presents a concise assessment of the soundness of the model. This section is followed by a section in which the method for the assessment of the model against the manageability and fit with the problem criteria is explained (Section 5.3). Consequently, Sections 5.4 and 5.5 evaluate the model against these two relevance criteria. The evaluation of the model against the third relevance criterion, timeliness, is presented in Section 5.6. Finally, the chapter ends with a discussion and conclusion in Section 5.7. Previous versions of part of this chapter are published elsewhere (Kraaijenbrink, 2005b).

5.2 Assessment of the Soundness of the Model

Subsection 1.2.2 presented the criterion of soundness. As explained there, soundness refers to a carefully defined domain of validity and rigorous foundations of the maintainability of the specific claim that is attached to the model (De Leeuw, 1999: 190). It is decomposed into the criteria of consistency, precision, and correctness. The past four chapters reflect an attempt to develop a sound systemic KI model. The model was demarcated in Chapter 1, it was founded on the literature in Chapter 2, it was grounded in empirics in Chapter 3, and it was framed by Parsons' social systems theory in Chapter 4. Although a full empirical test of the consistency, precision, and correctness of the systemic model lies outside the scope of this study, we can make an assessment of the model against these three criteria by the way it was developed.

Consistency

Put simply, a model is consistent when it contains no internal contradictions (Popper, 1959: 72). In Subsection 4.2.2 it was remarked that Parsons' theory is often claimed to be inconsistent. One of the strongest of these claims can be found in the conclusion of Savage's book: "The conclusion of this work is, therefore, that Parsonian theory, whether epistemological or sociological, is not a coherent body of concepts on which to base a social theory" (1981: 243). Hence, it seems that a model that is based on Parsons' model is inevitably inconsistent.

However, when we look at the kind of inconsistencies in Parsons' model, this is not necessarily the case. First of all, inconsistencies are not surprising when we consider that Parsons' theory is very complex and developed over a number of decades. The consistencies that appear during the development of Parsons' theory are not so much inconsistencies within Parsons' theory as inconsistencies between different versions of his theory. An example is the four function paradigm, which was sometimes based on respectively one dimension, two dimensions, and four dimensions (Blain, 1970). By choosing one version of this paradigm, we have avoided this kind of inconsistency. Other types of inconsistencies are in Parsons' dealing with empirics; in his own reasoning compared to his theory (e.g. often Parsons is an idealist while he refutes idealism in his theory, Alexander, 1983: 308); and in his application of his theory to a variety of fields. These kinds of inconsistencies, however, are not relevant for this study because we use our own methods, we are not Parsons, and we apply his theory to another field than Parsons has done. Hence, we believe that some of the most discussed inconsistencies of Parsons are not relevant to this study.

We have tried to avoid other inconsistencies by developing the model systemically from some general characteristics mentioned in systems theory, via Parsons' social system theory, to a systemic KI model. From systems theory we have used the general characteristics of systems to organize the systemic KI model. These general characteristics are mentioned by multiple authors and seem to be generally accepted amongst system theorists. Together, these characteristics constitute an organized and we believe relatively consistent model of a system. Although we have not systematically tested the consistency of the systemic KI model of Chapter 4, we have no reason to believe that it suffers from inconsistency more than existing models do.

Finally, we have to put the criterion of consistency somewhat in perspective. Although some scholars apply this criterion very strictly (e.g. Popper, 1959: 72), others suggest that because of the use of natural language in their reasoning only few theories in the social sciences are fully consistent. An example is Hannan & Freeman's (1984) theory of organizational ecology. While highly cited (almost 800 times by October 2005), it is found that this theory is not fully consistent (Peli et al., 1994). Hence, it seems to us that while the criterion of consistency is worthwhile aiming at, a theory or model should not be refuted when it is not completely consistent.

Precision

The second criterion for assessing the soundness of a systemic KI model is precision. This criterion concerns the accuracy of the model in terms of the set of phenomena the model refers to (Popper, 1959: 105). For example, a very precise definition of the four system functions of a systemic KI model would refer to a narrow set of KI activities in practice and would exclude other KI activities. The appropriate level of precision of a systemic KI model is hard to establish. When we follow Merton, we should aim at a 'medium' level of precision. According to him, we should try to develop theories of the middle-range, which are "theories intermediate to the minor working hypotheses evolved in abundance during the day-by-day routines of research, and the all-inclusive speculations comprising a master conceptual scheme from which it is hoped to derive a very large number of empirically observed uniformities of social behavior" (Merton, 1968: 5-6). One of the major critiques on systems theory has been that it is too vague and general to be useful as a theory in itself. We can largely agree to this, which is exactly the reason as to why we have used (social) systems theory only as a framework. In order to develop a model that is more precise, we have invoked the KI literature and the results of the empirical study. Hence, using Merton's terms, the systemic KI model is not a 'master conceptual scheme'. On the other hand, since the model reflects an attempt to structure the current fragmented body of knowledge on KI, we believe the model also is not a set of 'minor working hypotheses'. Hence, as we believe that the systemic KI model falls in between the two extremes sketched by Merton, we could conclude that the model is sufficiently precise.

However, it also depends on the purpose of the model what would be the appropriate level of precision. In Chapter 1, we have argued that the model should support KI problem solving in practice. In terms of precision, this suggests 1) that the model should concern KI and not all other phenomena, and 2) that the model should be sufficiently precise to apply in practice. Since the literature on which the systemic KI model was based specifically concerns KI, and not other phenomena, we assume that the model is sufficiently precise concerning the 'KI aspect' of this criterion. Concerning the 'apply in practice' aspect, our intention is to develop a general model of KI that would be applicable to a wide range of fields. We have chosen to focus the empirical analyses of this study on the context of NPD in high-tech SMEs. While in terms of generalizability of our results it is not sure whether the model will be applicable to other fields (see Chapter 6), in terms of precision we can see in Chapter 4 that the characteristics of the model are not necessarily limited to the high-tech SME context. None of the seven characteristics of the model is formulated in such a way that it would only apply to high-tech SMEs. By making the model more precise it would probably lose its applicability to some industries, which was not our purpose. For example, by specifying the types of technologies that are part of the KI system, we would have excluded some industries. Summarizing this discussion, we believe that the model is not inherently too broad or too precise to be used for KI problem solving. However, we do believe that with respect to the terminology used in the model further specifications are needed when the model is to be used by practitioners. The model is currently formulated in a way that would probably be too abstract for the language that practitioners use (see, for example, Subsection 3.2.2).

Correctness

The final soundness criterion that De Leeuw mentions is correctness. It concerns the question as to whether the model is a valid representation of KI in practice. This criterion is somewhat problematic in its application to conceptual models. Conceptual models consist of concepts, which in themselves are not testable (De Leeuw, 1999: 199). Also, in their role as a lens or thinking model, it is not necessarily relevant whether conceptual models are true or false. This can be explained by invoking Parsons' discussion of theoretical and empirical systems: "Methodologically, one must distinguish a theoretical system, which is a complex of assumptions, concepts, and propositions having both logical integration and empirical reference, from an empirical system, which is a set of phenomena in the observable world that can be described and analyzed by means of a theoretical system" (Parsons, 1977: 177). From this short discussion it can be inferred that a systemic KI model is not intended to be a true representation of the KI phenomenon. Rather, it is a means to describe and analyze the KI phenomenon. The problem with applying the correctness criterion to conceptual models also is apparent when we consider the work of Morgan. Morgan (1986) provides eight different views on organizations (for example, organizations as machines, as organisms, and as brains). It is not very plausible that each of these views is a true representation of organizations in practice. However, by highlighting different aspects of the complexity of organizations, these views can provide numerous useful insights. Hence, the quality of these views depends on the goal they are used for rather than on their truth. Similarly, Jarvie (1973) argues that functionalism (a branch of systems thinking) seems to be false or tautologically true but also very fruitful.

Given these considerations, we can argue that the correctness of a systemic KI model per se is less important than the correctness that appears in its use (De Leeuw, 1999). A systemic KI model is correct when it does what it claims it does. When discussing the objectives of this study we have argued that the goal of a systemic KI model is to provide an organized model of KI with which we are able to identify, explain, or solve KI problems that without the model are unlikely to have been identified, explained, or solved. The objective of providing an organized model is what Jarvie seems to refer to when he argues that functionalism is tautologically true: a systemic KI model by definition provides an organized model of KI. The second part of the objective concerns the use of the system. We can evaluate whether the systemic KI model indeed can support the identification, analysis, and solving of KI problems that without the model would likely to have remained unidentified, unanalyzed, or unsolved. Since this, however, concerns the relevance of the model rather than its soundness, this is discussed in the next section.

Conclusion on the Soundness of the Systemic KI Model

Although, above, the soundness of the model was only evaluated by considering how it was developed, and not by an empirical test, we believe this is sufficient for this stage of the research. In the development of the model we invoked (social) systems theory, the KI literature, and an international empirical study. Together, these ingredients should have led to a model that is sufficiently consistent, precise, and correct for the model development stage this study is in. Since, like in business, resources are not unlimited in science, researchers should take into account the efficiency (De Leeuw, 1999) or practicality (Cooper & Schindler, 1998) of the research. Rather than further testing the soundness of the model, we believe it to be desirable to first evaluate the relevance of the model. Otherwise we run the risk of developing a model that is very sound, but useless.

5.3 Method to Assess Manageability and Fit with the Problem

This section explains the method that was followed to assess the systemic KI model against the first two of the three relevance criteria: manageability and fit with the problem. The third relevance criterion, timeliness, will be evaluated in Section 5.6. After discussing the type of data needed for the assessment of the model against the first two criteria (Subsection 5.3.1) we discuss the data collection method (Subsection 5.3.2), a characterization of the sample and the data (Subsection 5.3.3), and the method of analysis (Subsection 5.3.4).

5.3.1 Type of Data Needed

In order to evaluate the systemic KI model against empirical data, we start with a discussion on what type of data would be needed to make this evaluation. Hence, this subsection elaborates on the type of data that would be needed to evaluate the model against the manageability criterion and the fit with the problem criterion.

Manageability

Put simply, a model is manageable when it is easy to use. Following De Leeuw (1999), it can be argued that a model is manageable when it is 1) not too complex, 2) instantiated in an practically usable form, and 3) understandable. With respect to the understandability of the model, Section 5.2 already argued that the language in which the model is currently formulated is probably too abstract for practitioners. While the focus there was on the precision of the model, the use of somewhat abstract scientific language also means that the model is probably not easily understood by practitioners. Hence, with respect to this aspect, the model is not manageable. Concerning the form in which the model is instantiated we can already conclude at this place that an instantiation in figures and text in a PhD thesis is probably not a practically usable form. Hence, also with respect to the form of the model, we can conclude that the model is not manageable. While we do recognize that the lack of manageability in terms of understandability and form are important barriers to using the model in practice, we feel that at this stage of the research we should first focus on the third aspect of manageability: the complexity of the model. Before bothering about terminology and form, we feel we should bother about concepts and their empirical reference. Therefore, we accept that the current version of the model will be hard to understand and use by practitioners and move on to the issue of complexity. We will return to understandability and form in Chapter 6, when we discuss directions for further research.

By including notions from the KI literature, empirics, and (social) systems theory, we have tried to develop a sound systemic KI model (see Section 5.2). As a result of this endeavor, the model has become complex. As such, we can see that the manageability criterion can be in conflict with the criterion of soundness (as also argued by De Leeuw, 1999): a conceptual model that is correct, consistent, and precise, runs the risk of becoming complex, which in turn diminishes its manageability. Hence, in order to improve the model with respect to its manageability, this chapter should assess whether the model can me made less complex without losing its soundness. In terms of analysis, this means that we should investigate whether and what parts of the model could be omitted without much loss of its soundness. In order to do so, we need a *variety* of examples of KI in practice. Variety is needed because we need to get a high coverage of the ways KI is performed in practice. Without variety, there is the risk of omitting parts of the model that are perhaps not relevant for a subset of KI, but that can be very relevant for another subset. Also, it is important that the systemic model is not yet imposed on the collected data: if we use the systemic model to collect our data, it becomes a self-fulfilling prophecy in that we will undoubtedly find evidence for each of its characteristics. Hence, for the manageability criterion we need a high variety of KI examples of which the data collection is not guided by the systemic KI model.

Fit with the Problem

The second relevance criterion concerns the question whether the systemic KI model is doing what it is supposed to do. As presented in Chapter 1 and repeated above, its objective is support the identification, explanation, and solving of KI problems that without the model are unlikely to have been identified, explained, or solved. Hence, concerning this criterion, this chapter should evaluate to what extent the model is indeed able to do this. With a model that is fully developed and operationalized this could probably best be done by an experimental setting in which practitioners with the model and practitioners without the model are compared. In such a case, the model would be used as an intervention. However, in the current stage of the model this is not feasible, implying that we have to evaluate the model in another way.

Considering that for the manageability criterion we need examples of KI in practice, it is most efficient if we can use similar examples to evaluate the model's fit with the problem. We believe this to be feasible and appropriate. The main difference is that for this purpose, rather than variety, it is more important to have detailed and elaborate examples. It seems unlikely that for the solution of a particular KI problem all characteristics of the systemic KI model will be needed. In order to evaluate whether the model is able to support KI problem solving not the coverage of the model is important, but its depth. The examples can then be analyzed using the model in order to identify problems and/or solutions that were not detected yet.

5.3.2 Data Collection Method

As argued before, in a social system activities play a central role. Combined with the need for variety and detail that was expressed in the previous subsection, this implies that the data to be collected should consist of a variety of detailed examples of KI activities in practice. The need for both variety and detail eliminates a large share of the repertoire of available data collection techniques: in order to get a large variety, we need many examples and in order to get detail, we need in-depth examples. To get variety, a large-scale survey seems appropriate. However, with such a survey it is very hard to get in-depth examples. On the other hand, case study research would provide us with in-depth examples. However, since it would only be feasible to conduct a small number of case studies, this would reduce the variety of the examples. As a compromise between the two, we have chosen to conduct a multi-site study where in-depth examples are collected from a number of sites. In the typical dichotomy between a survey (hundreds of cases, shallow) and a case study (mostly less than ten cases, in-depth) the type of data provided by such a multi-site study would be positioned in the middle (tens of cases, medium depth).

A consequence of choosing data of a medium depth is that we will not be able to assess the model as a whole. As we will collect multiple relatively small examples of KI in practice, it is highly unlikely that we will be able to apply the model as a whole to a particular in-depth example. To do so would typically require a longitudinal case study in which a KI system in practice is followed for a longer period. Within this study it was not feasible to conduct such an additional case study. Hence, we will not be able to illustrate the full potential of the model within this study. Nevertheless, we believe that by focusing on each of the seven characteristics of the model it is to a large extent possible to assess the model's manageability and fit with the problem.

Data Gathering Technique

The abstraction from underlying disciplines that is made in the systemic KI model and the fact that KI activities can contribute to multiple functions make data gathering a difficult task. The challenge is how to collect empirical data without biasing it to a particular discipline and/or a particular KI function. An interview scheme containing questions about each of the characteristics of the systemic KI model would only force the preconceptions of this study rather than evaluate the model (Glaser, 1992). Therefore, we searched for an approach that would reduce the influence of our preconceptions on data collection to a minimum and restrict the use of the systemic KI model to data analysis. This type of approaches is found in the literature on inductive theory building. There we find that it is important – if not crucial – to get a rich and holistic picture of the phenomenon under study (Lee & Baskerville, 2003; Miles & Huberman, 1994). Spradley (1980) recommends highly intrusive techniques as participant observation for this type of research. However, since KI is an intangible process and not performed at one point in time, it is impracticable, if not impossible, to use this technique successfully. A more appropriate technique is the critical incident interviewing technique (Flanagan, 1954), which is defined as follows:

> *"The critical incident technique consists of a set of procedures for collecting direct observations of human behavior in such a way as to facilitate their potential usefulness in solving practical problems and developing broad psychological principles. The critical incident technique outlines procedures for collecting observed incidents having special significance and meeting systematically defined criteria. By an incident is meant any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act. To be critical, an incident must occur in a situation where the purpose or intent of the act seems fairly clear to the observer and where its consequences are sufficiently definite to leave little doubt concerning its effects"* (Flanagan, 1954: 327)

Using the critical incident technique (CIT), interviewees are asked to elaborately describe successful and unsuccessful examples of the process under study. Crucial for this type of interviews is that interviewees can concentrate on description and are not distracted by asking for explanations of their behavior. If explanations are needed, these should only be asked after the description.

The CIT is recognized as a valid, reliable, and effective method for gathering rich qualitative data for a variety of purposes, including the analysis of information behavior (Andersson & Nilsson, 1964; Fisher & Oulton, 1999; Urquhart et al., 2003). It also has been applied successfully in SMEs across a range of business sectors (Chell, Haworth, & Brearley, 1991) and is particularly suited for multi-site studies and comparative work (Chell, 2004). Of the available interviewing techniques, the CIT is considered to give one of the most accurate and reliable retrospective reports of processes in practice. "One disadvantage is that the accounts are always retrospective; however, the fact that the incidents are 'critical' means that subjects usually have good recall" (Chell, 2004: 47). Also, although respondents might resist providing unsuccessful incidents, the explicit focus on both successful and unsuccessful incidents provides a means not to be carried away by the wave of success which the respondent may be presenting (Chell, 2004; Denrell, 2003). This will provide a more realistic view of KI in practice. Considering the advantages and suitability of the CIT, this technique was chosen for the data collection of this part of the study.

Demarcation of the Incident

A key step of the CIT is the demarcation of the incident. Since the systemic KI model contains four system functions and their interchanges, this is not a trivial task. For example, if respondents would be asked to describe a case in which they had *searched* for knowledge, this would have biased the interviews towards goal attainment. If they would be asked for a case in which they had *used* external knowledge, this would bias the interviews towards successful KI. On the other hand, if they were asked to describe cases of knowledge integration, they would either not understand the question or need a detailed explanation of the concept.

Since none of these demarcations of incidents would cover the full scope of KI activities *and* would still be recognizable for respondents, an alternative approach was chosen. During the exploratory interviews (see Chapter 3), goal attainment KI was obviously most recognizable for respondents: they could relatively easily describe how they had searched for particular knowledge and used it for their NPD. Moreover, examples of this type of KI turned out to be remembered relatively easy. Also, this type of KI scored highest in the quantitative study in terms of frequency (see Chapter 3). Therefore, we decided to focus the interviews on goal attainment and hope that respondents also would touch upon the other functions during their descriptions. If, after the first interviews it would turn out that this strategy would not be successful, the strategy would have been altered accordingly. However, after a few interviews it appeared that changing the strategy was not necessary because respondents also included other types of KI in their descriptions.

Thus, in the interviews, respondents were asked to describe recent examples ('incidents') in which they needed knowledge from outside their company in order to solve a certain NPD problem. Moreover, in order to be 'critical' these incidents should be either successful or unsuccessful. Since the incidents concerned goal attainment KI processes, success is defined as the extent to which the NPD problem was solved. While we thus requested successful and unsuccessful incidents we are not so much interested in the question whether an example was successful or not. This would be relevant when our objective was to explain KI success. As indicated, however, this is not our objective. Rather, we requested successful and unsuccessful examples to get as much variety of examples as possible.

Interview Scheme

Based on this demarcation of the critical incident, a semi-structured interview scheme was developed consisting of a general part, a critical incident part, and a part for additional elicitation. The purpose of the general part of the interviews was twofold. Firstly, it helped the interview*er* to get a rich picture of the context and the general way in which KI took place in the company. Secondly, it prepared the interview*ee* to the type of critical incidents to be described in the second part of the interview. This part included the following topics:

- Description of the company, its products, markets, and recent and future developments.
- Description of the general NPD process in the company, including the role of the interviewee.
- Description of the general KI process during NPD in the company, including the identification, acquisition, and utilization of knowledge from external sources.

The second and main part of the interview was used to get a description, explanation, and reflection of at least one successful and one unsuccessful incident of KI in the company. To not distract interviewees from their description, explanatory and reflective questions were only asked after the description was given. Interviewees were asked about the following topics for each incident:

- Description of a specific example of KI during NPD in the company, including the identification, acquisition, and utilization of knowledge from external sources.
- Explanation of why they acted in the described way.
- Reflection on problems and potential improvements.

The last part of the interview was used to elicit additional details for the incidents by confronting the interviewee with a number of classifications from the literature of the types of NPD problems, knowledge needs, knowledge, and knowledge sources. Providing respondents with such classifications could trigger respondents to think again about their answers and could help them to remember additional details. The interview scheme is included in Appendix VII.

5.3.3 Sampling and Characterization of Response and Data

Type of Respondents

For the selection of the type of respondents, the following criteria should be applied (Hutjes & Van Buuren, 1992): the respondent must 1) have access to the required information; 2) be interested in the topic; 3) be willing and able to provide the researcher with the information he needs; and 4) be able to provide neutral information.

Considering these criteria and the experiences with respondent selection in the preliminary study, the targeted interviewees were engineers and NPD managers of high-tech manufacturing SMEs. The empirical study of Chapter 3 has shown that these respondents are knowledgeable, interested, and willing to talk about KI in NPD in their company. Whether they also provide a neutral account is less clear. Since they will talk about their own experiences, their account will always be biased by including their own perspective. However, the particular procedures of the CIT should form a protection against too much personal bias (e.g. by explicitly asking for unsuccessful incidents and by a focus on description, rather than explanation). Hence, we believe that engineers and NPD managers of high-tech manufacturing SMEs are the most suitable respondents.

Sampling Principle

It was not possible to rationally decide in advance how many respondents should be interviewed. Therefore, for the selection of interviewees, we used the principle of theoretical sampling (Glaser & Strauss, 1967). A fundamental characteristic of theoretical sampling is that the type and number of respondents are not established in advance, but result from the theoretical need for further exploration until saturation is achieved. Guiding principles for respondent selection are minimization and maximization of differences amongst between respondents. Following these principles, the enquiry started with a selection of four respondents in the electronics industry, two in the chemical industry, and one machine manufacturer (see Table 5.1, pseudonyms were used for reasons of privacy). After a first analysis of the seven interviews it was concluded that there was a need for additional interviews: (1) at one similar machine manufacturer (Coamac); (2) at one similar chemical company (Clensco); (3) at one engineering company (Inventi); (4) with two persons with different roles in one company (Protinc); and (5) at science based instead of technology based companies in one industry (Nanomu, Flunano). After analysis of these additional seven interviews, a point of saturation was perceived. That is, no new types of KI incidents were found anymore. To examine whether this was indeed the case, three additional interviews were done in very different companies (Polycom, Agrigen, and Memaco). In these three additional interviews also no new types of KI incidents were identified, which strengthened our confidence to have reached a point of saturation.

Table 5.1 Profile of respondents and their companies

Company	*Industry*	*# Empl*	*Year*	*Job*
First round				
Optimea	Electronics – optical measurement	2	1994	Director / engineer
Devan	Electronics – analogue devices	1	1997	Director / engineer
Eltrode	Electronics – control systems	7	2000	Director / NPD manager
Mediag	Electronics – diagnostic	50	1988	Engineer / NPD manager
Wax'em	Chemical – wax emulsions	35	1956	Engineer
Woodcoat	Chemical – coatings	20	1895	Engineer / NPD manager
Macman	Machine – specialties	90	1990	Engineer / NPD manager
Second round				
Nanomu	Nanotechnology – mechanical, optical, fluidic	16	2001	Engineer
Flunano	Nanotechnology – fluidic	6	2001	Director / Engineer
Coamac	Machine – coating	23	1970	Engineer / NPD manager
Clensco	Chemical – lubrication, cleaning	35	1991	Engineer / NPD manager
Inventi	Engineering – industrial series	10	1990	Engineer / NPD manager
Protinc	Engineering - process technology	23	1993	Director / NPD manager
Protinc	Engineering - process technology	23	1993	Engineer / NPD manager
Final round				
Polycom	Chemical – polymers	5	2002	Engineer / NPD manager
Agrigen	Genomics – agricultural	25	1998	Director / NPD manager
Memaco	Machine – membrane filtration	4	1995	Director / NPD manager

Characterizing the Data

The interviews lasted between 70 and 180 minutes, with an average of two hours. They were recorded and transcribed completely, accounting for a total of 768 pages of double-spaced transcribed text. Consequently, each KI incident that was described by the interviewees was decomposed into its parts and coded into MS Excel sheets (total number of critical incidents: 65).

In order to check for the variety of the data, the constant comparison method (Glaser & Strauss, 1967) was used to classify the various KI incidents that were described by the respondents. However, rather than starting from a *tabula rasa*, the comparisons were made with the functional patterns of KI activities of the systemic KI model. Thus, the followed approach is related but not identical to the grounded theory approach. Comparisons were made using the principles of minimizing and maximizing differences between cases. An example of minimizing differences is the comparison between Optimea and Devan: both companies are from the same industry, have about the same number of employees, were established in the same period, and were represented by respondents with a similar position. An example of maximizing differences on the number of employees is the comparison of these companies with Mediag: Mediag is similar to Optimea and Devan in terms of industry, and year of foundation but different in terms of number of employees.

The result of this analysis was that the 65 incidents represented instances of each of the four types of SFs, of learning and of interchanges between functions. Also, they represented each of the three KFs. Because of the interview protocol, interviewees described much more goal attainment incidents than any other KI function. Despite of the fact that the incidents are not evenly distributed amongst the functions, we can conclude that there is a sufficient amount of variety in the 65 incidents. Since the confrontation of the functional patterns of KI activities with the KI incidents also is part of the analysis, further details are given in Section 5.4.

5.3.4 Analysis Procedures

Using the 65 incidents, two types of analysis were conducted, referring respectively to the manageability criterion and the 'fit to the problem' criterion.

As indicated, the main objective for the manageability criterion in this study is to evaluate whether the model can be made less complex. Our assumption is that when some part of the systemic model is not needed to model any of the 65 incidents, it can be omitted. Hence, in order to evaluate the systemic KI model we went systematically through each of the seven system characteristics and their specifications and compared them with the 65 incidents. When, in none of the 65 incidents the respective specification was needed to model the incident *and* when we could find an explanation why it was not needed, we declared it superfluous for studying KI in the context of NPD in high-tech SMEs. The requirement for an explanation is added because an empty category could also mean that the data are not sufficiently rich. The result of this analysis will be an adjusted version of the systemic KI model of Chapter 4.

The second type of analysis concerns the extent to which the reduced systemic KI model 'fits with the problem'; that is, is likely to support KI problem solving. The basic idea of a model that supports the identification of new KI problems and/or solutions is that it enables the user to make new choices or decisions. Or, in other words, the model gives the user additional 'handles' to manipulate KI. Therefore, in order to evaluate the model against this criterion, we illustrate which kind of new choices can be made with the model. Using a subset of the 65 incidents, we went again systematically through each of the seven system characteristics. We evaluated whether in a specific case, considering that particular system characteristic, the model could help to identify choices that are less likely to be identified without the model.

For these two types of analysis, the same data was used. For the manageability criterion the KI incidents are used to analyze the model. On the other hand, for the 'fit to the problem' criterion the model is used to analyze the incidents. Since this second analysis is completely different from the first analysis, the double use of the incidents is not problematic. Rather, it is an efficient way to use the same data for two different purposes. While for the manageability criterion the data is used to reduce the complexity of the model itself, for the fit with the problem criterion the data is used to evaluate whether the *use* of the model leads us somewhere. Also, while for the manageability criterion the variety of the full set of incidents is used, for the fit with the problem criterion we focus on single incidents in-depth.

5.4 Results: Manageability of the Systemic KI Model

In order to evaluate the manageability of the systemic KI model, this section evaluates for each of the seven system characteristics whether we can find examples in the incidents. The central question here is whether the characteristics do instantiate, and if so, how. The assumption is that, in general, when a characteristic instantiates in one or more of the 65 incidents it should be part of the systemic KI model.

5.4.1 Elements of a KI System

Subsection 4.4.1 has presented four types of system elements that each will be evaluated below: actors, technologies, KI activities, and knowledge.

Actors

In the systemic model, actors are attributed three types of roles: in relation to the system they operate in (representative, professional, and specialist), in relation to external systems (as shared work producers, shared work practitioners, expert-seeking novice, and secondary knowledge miner) and in relation to the controlling organ of the KI system (controlling organ, and target system). In the incidents, we have found numerous examples of these types of roles, of which we will provide a number of them below.

The role of *representative* appeared, for example, at Eltrode, where the director of the company was responsible for all the information exchanges with the customer, whatever the topic was. While this is an example of a representative role at the recipient system, this role also was found at the source system. The director of Protinc mentioned that when contacting another company, the hardest part is often to get past the secretary. As such, the secretary represents the source company. A related remark was made by an NPD manager at Woodcoat about marketing people: companies' websites are often created by the marketing department. As a result, on the Internet, these companies are represented by their marketing department. The role of *professional* appeared in virtually all the 65 incidents. The general way of working seems to be that you try to do as much as you can on your own and only when you need additional expertise you contact others, including your colleagues. This was most obvious at Devan and Optimea, where the company consisted of respectively one and two persons. However, also at the other companies this role appeared numerous times. The same is true for the role of actors as *specialists*. Examples are that at Polycom and Eltrode a number of engineers with different specializations and expertise cooperated in one project. This is an example of specialists working in parallel. Another example is at Coamac, where a project leader collected knowledge on the general type of solution that would solve a problem in a new machine and subsequently, engineers had to find out how to realize this solution in detail. In this example, the specialists work in a serial way. When considering these examples, it appeared that the difference between professionals and specialists is very hard to make in practice. Within their specific field, people can be regarded as professionals: they are relatively autonomous and knowledgeable about their work. However, as soon as they need to do something that is outside that field, they can be regarded as specialists that are dependent on others and are less knowledgeable. Because, in the practice of NPD in high-tech SMEs, people constantly work in their own field and in new fields, the difference between the two roles is very hard to make. Hence, we believe *the role as professional can be omitted* without any substantial loss of the richness of the model.

Concerning the role of actors in relation to external systems, the role of *shared work producer* appeared in many incidents, often in the form of a cooperation between the company and its customer. One example is Devan, where in the development of a sensor for registering internal body movements, the company cooperated face-to-face with its customer in order to obtain the specifications of the customer. Also of the role as *shared work practitioner* we can find examples in the incidents. Also at Devan, the director discovered a bug in one of the chips of a large chip manufacturer. After unsuccessfully trying to find information about this bug at the manufacturer he went to an online discussion forum. There he found out that others had encountered similar problems with the chip. Using the information he found there, he was able to find an alternative for the chip. An example of the role as *expert seeking novice* is Protinc where a customer, who was the owner of a horse stable, encountered the problem that the soil that was used in the stables became polluted too frequently. As this problem was completely new for Protinc, the director asked a personal friend (who was a veterinarian) to gather some relevant information when he would visit a number of stables. Finally, concerning the role as *secondary knowledge miner*, an example is at Nanomu where an engineer receives new and relevant scientific publications and dissertations from a university in exchange for supervising master students and PhD students. While these publications were made for scientific purposes, they are now used by Nanomu for its product development. Since, thus, each of the four roles of actors in relation to external systems appeared in the incidents, these should appear in a systemic KI model.

The final type of role that was distinguished was the role of actors in relation to the control function. In the incidents, we saw that this role often relates to who is initiating the NPD process. In some cases there was a specific request (or even demand) from a customer to develop something. An example is Wax'em, where one of its customers requested a cheaper alternative for a particular acid. In this example, Wax'em's customer to a large extent controlled Wax'em's KI process by defining exactly what the outcome should be. In other cases, the SME itself controlled its KI activities. An example is Woodcoat, where the NPD manager decided that he should try to find a water-based alternative for a particular solvent. From these examples we conclude that also this third type of roles appears in practice and therefore should be part of a systemic KI model.

Information Technologies and Non-Information Technologies

A second type of system elements are the (non-)information technologies that are used to perform KI activities. As the use of computers for searching the Internet is common nowadays, it needs no explanation that in the incidents information technologies are used to perform KI activities. Additionally, in the incidents, also non-information technologies were used for this purpose. An example is the use of measurement instruments (at Optimea, Eltrode) to obtain knowledge about a particular component. Another example is the use of production machinery (Nanomu, Flunano), where engineers had to test whether a newly developed machine part indeed operated in the way it was supposed to do. In both these cases, non-information technologies were used to obtain particular necessary knowledge. Hence, both information technologies and non-information technologies should be included as elements of a systemic KI model.

KI Activities

A third type of element that was mentioned is the KI activities. We believe it does not require any further explanation or examples that a systemic KI model cannot do without KI activities. Rather than providing specific examples at this place we refer to Subsection 5.4.4, which discusses their patterning.

Knowledge

The final type of element that was distinguished, is knowledge. As discussed in Subsection 4.4.1, knowledge resides in actors, information technologies, non-information technologies, and activities, and in combinations of them. We have found examples of each in the critical incidents. An example of knowledge residing in *actors* is Memaco where the company hires students from the university to do their internship because they have the skill to perform a market study. Another example are Polycom and Nanomu where one particular professor was consulted on a regular basis since he is considered to be a guru in the field. While these two examples concern cases of knowledge that already resides in actors, there also were examples of increasing the amount of knowledge residing in actors. An example is Macman where the NPD manager followed a course. Examples of knowledge residing in *information technologies* are numerous, like magazines (Mediag), books (Flunano), scientific journals (Nanomu), newspapers (Memaco), project documentation (Nanomu, Inventi), a database of gene structures (Agrigen), a corporate library (Devan), and CDs with customer data (Woodcoat). Examples of knowledge residing in *non-information technologies* were numerous as well. Two examples that were frequently mentioned are suppliers' components (e.g. Devan), and competitors' products (Clensco, Nanomu) as sources of knowledge. Additionally, we can find examples of knowledge embedded in *activities*. This was most obvious in the two nanotechnology companies (Nanomu and Flunano) where their main reason of existence is that they know or can find out how to produce certain microchips. The design of the microchip in itself is considered as relatively easy compared to the design of the process to create it. Finally, in the incidents, knowledge also appeared to be embedded in *combinations* of the several elements. For example, the NPD manager at Mediag mentioned that in order to assess the suitability of a company as a supplier, he had to get a 'feeling' of what the company would be like. By looking for a number of indicators (e.g. size, type of product, type of customers) the NPD manager was able to 'construct a picture' of the respective company. Another example is Woodcoat where the interviewee had to visit the site of another company in order to understand what they were exactly doing. A final example is several remarks that information seeking is not so much a matter of finding the right information, but more of combining (Polycom), solving a puzzle (Flunano, Clensco), or creating a 'knitting' (Memaco) of information. Since we found numerous examples of knowledge embedded in each of the other system elements and their interactions, we believe the systemic KI model does not need modification on this aspect.

Implications for the Systemic KI Model

As we have found numerous examples of each of the elements of a KI system as they were mentioned in Subsection 4.4.1, we conclude that the model can remain virtually unmodified concerning its system elements. One exception concerns actors' role as professional. As argued above, this role appeared superfluous in all the incidents because of its similarity to either the role as representative, or the role as specialist. Hence, we suggest to omit this role from the systemic KI model.

5.4.2 Boundaries of a KI System

In the 65 incidents, the notion of a system boundary appeared not unproblematic. Firstly, concerning the location and origin of the system boundary, there were many differences. For example, for Eltrode and Optimea there seemed to be a dyad of two companies that together could be seen as the KI system. Both Eltrode and Optimea are designing firms that have outsourced part of their production to another company. Eltrode and Optimea intensively cooperated with these production companies and exchanged knowledge on an almost ongoing basis. Alternatively, at Mediag, Coamac, and Clensco, there seemed to be a rather stable network of multiple companies which could be considered as the KI system. Or differently, at Nanomu, for example, a university professor was consulted so frequently, that he could be considered as part of Nanomu's KI system. Hence, there does not seem to be a straightforward way to define the boundaries of a KI system.

Secondly, also the nature of the system boundaries appeared problematic in the various cases. Rather than being stable for some period, system boundaries seemed to change all the time. For example, during a KI process, on the one hand, companies established new potentially long-term relationships. An example was Agrigen where the director explicitly was looking for partners in Israel, South-Africa, and China. On the other hand, it also happened that companies did not consult their existing long-term relationships at all because the problem at hand was completely new for them (Optimea). Also, it seems that system boundaries are different for each particular NPD process because each NPD process requires different knowledge. This was the case, for example at Protinc, where virtually every project is different in terms of required knowledge.

Thirdly, although open systems theory already considers system boundaries to be permeable, it still considers the maintenance of system boundaries one important task of the system. On the contrary, in the interviews it appeared that in the particular context of NPD in high-tech SMEs exactly the crossing of system boundaries is one of the main characteristics of the KI process. In all incidents, knowledge is taken from one context (i.e., an external KI system) and translated to another context (the focal KI system) where it is incorporated into a new product. It probably is the very nature of NPD that knowledge is not available within the same domain as the SME. If it would be available, the SME could just apply it without further efforts. However, in many cases the knowledge is not available. Rather than generating it themselves, SME try to find similar knowledge in a domain that is close to their own domain. Once found, they translate it to their own situation in order to apply it. An example is at Flunano, where a small fluid container, which is normally used for the storage of insulin for diabetes patients, was used for the storage of medicine in a medicine sprayer. In this case, Flunano faced the problem that no one before had thought of this application for the container. Consequently, this application was not described while the same fluid container could be used. This example illustrates that knowledge that is similar in different domains on one level of abstraction (e.g. the function of storage of a liquid) is different on other levels of abstraction (e.g. its application in an insulin pen and a medicine sprayer). Even more explicit this also appeared at Inventi where the difference between application domain, function, form, and production process was explicitly used as a means to bridge knowledge from different domains. Hence, it seems that, in the particular context of NPD, system boundaries are so permeable and dynamic that they hardly exist.

Implications for the Systemic KI Model

We believe that, considering these problems with establishing boundaries of a KI system, it is not desirable to maintain the concept of a system boundary in a systemic KI model. It appeared that it was only possible to draw system boundaries for each particular incident of KI in NPD. For each incident we can, for example, establish which the involved actors are and what their contribution is. Hence, this would create a snapshot of a particular 'system'. From a systems theory perspective this does however not make any sense. A system is not a snapshot; it is only a system when it exists for at least some period in which it is more stable than its environment. Also, when we make this snapshot, there is no interaction with the environment anymore: all actors that interact are included in the system; the rest is left outside the system. Hence, there would be no open system anymore. The apparent lack of a system boundary seems to impose some problems on the notion of a system: if there is no boundary, how can we speak of a system? Hence, we believe there is a need for an alternative conceptualization of a KI system boundary rather than 'simply' omitting it.

Considering the aforementioned problems with the current boundary concept, we suggest that, alternatively, a KI system should be seen as a city. Consider a city that consists of a densely populated center and that gradually becomes less densely populated near its peripheries. Eventually, the city gradually dissolves in the environment by an occasional farm or land house. When applying this metaphor to KI, the density of a KI system could be considered to be the extent of interaction between system elements (actors, technology, KI activities, and knowledge). A KI system, then, consists of a rather dense kernel (e.g. a number of engineers in a high-tech SME). The kernel is surrounded by a periphery of other actors that is relatively dense near the kernel and becomes gradually less dense (i.e. interaction becomes less). This is depicted in Figure 5.1, in which the knots correspond with elements of the KI system and line thickness corresponds to the density of their (direct or indirect) interaction *with the kernel of the KI system*. Elements at the periphery of the KI system might interact heavily with each other. However, what matters in this case are only those interactions that relate to the kernel of the system.

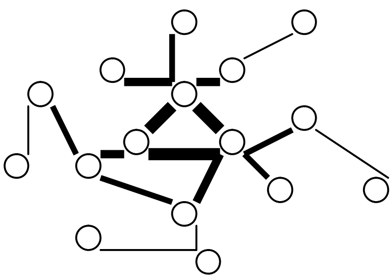


Figure 5.1 The KI system as a city

The metaphor of a city can be extended. Although cities have official boundaries, in practice these may not really matter. For example, traffic crosses the boundaries of a city and might be heavier between part of one city and a part of another city than within a city itself. We have seen the same for a KI system where the formal organizational boundaries are not necessarily relevant (see Subsection 4.4.2). Also, cities change all the time: people move, houses are built and new roads are built. We have seen same for KI. Although the city metaphor is helpful to reconceptualize a KI system boundary, there is the risk of overexploiting it. Therefore, we will leave the metaphor for what it is. Rather, we suggest that instead of the system boundary concept, the concept of interaction density should be used to distinguish a system gradually from its environment.

Interaction density provides a means to locate and characterize a KI system in relation to its environment. However, it does not yet provide an explanation of the origin of system 'boundaries'. Namely, while a boundary implies that there is something to be bridged, interaction density does not say anything about whether and what should be bridged. To deal with this problem, we believe the concept of a *barrier* is helpful. While a boundary implies a rather stable KI system that is bordered by a particular type of boundary (e.g. geographical boundary, or a language boundary), the concept of a barrier is more flexible and more consistent with what was said above about bridging contexts in NPD. It allows different types of barriers between different actors and allows actors to get around certain barriers. For example, the barrier between engineer A and B might consist of a lack of specialized knowledge; the barrier between engineer A and C of a lack of a shared language; and the barrier between engineer A and D of commercial conflicts of interest.

Hence, rather than using the notion of system boundaries we suggest using the notions of interaction density and interaction barriers between system elements to distinguish a KI system from its environment. This provides a conceptualization of a KI system that fits better with the 65 incidents that were evaluated. As we will demonstrate in later subsections, this representation of a system also more accurately represents some other characteristics of KI in practice.

5.4.3 Internal Structure of a KI System

With respect to the structure of a KI system, Subsection 4.4.3 has suggested that a KI system should distinguish three knowledge functions (KFs: identification, acquisition, and utilization), four system functions (SFs: adaptation, goal attainment, integration, and pattern maintenance), a controlling organ (CO) and a target system (TS), and two levels of aggregation (group and organization).

Concerning the KFs, Subsection 4.4.3 has suggested that the three KFs should be distinguished at two levels of aggregation: identification, acquisition, and utilization of knowledge from outside the KI system, and from other subsystems within the KI system. As Chapter 3 has shown, in practice, KI activities are performed that contribute to each of these functions at both levels. That chapter also has shown that these KI activities do not pattern into KFs, which implies that KFs should not be seen as separate subsystems. However, the fact that the KFs do appear in practice and represent theoretically distinct categories of KI activities, suggests that KFs should be considered in a systemic KI model. As the next subsection will show, also in the incidents numerous examples are given of KI activities that contribute to these functions. Hence, we conclude that KFs should be included in a systemic KI model.

Concerning the SFs, we have observed in Chapter 3 that each of the four SFs appears in practice as patterns of KI activities. As the next subsection will show, also the incidents provided examples of each of these functions. Hence, we can conclude that the four SFs should be recognized in the structure of a KI system. An interesting question remains whether these functions appear as concrete subsystems or not. When they would appear as concrete subsystems, this would mean that different actors and technologies would perform the different functions. When we look at the incidents, we see, however, that this is not the case; the same actors and technologies perform the four functions. An example is how the same computers were used for a targeted search for knowledge (goal attainment function), and the dissemination of knowledge in the SME (integrative function). Another example is how the same individual persons searched for specific knowledge (goal attainment function) and scanned their environment for general interesting knowledge (adaptive function). As these examples apply to virtually all incidents, we can conclude that the four SFs do not instantiate as concrete subsystems in practice. However, as argued above, this forms no reason to not distinguish them in a systemic KI model.

Concerning the control function and the aggregation levels of a KI system, Chapter 4 has suggested that a systemic KI model should distinguish KI systems and subsystems, each having their own CO. When we look at the incidents, we see that the control function does indeed appear at the level of subsystems: goals are formulated and learning takes place within each of the four subsystems (this will be illustrated in Subsections 5.4.6 and 5.4.7 where we discuss the control function in more detail). Although goal formulation and learning did not always take place explicitly in the incidents, there is thus little doubt whether the control function at this level should be included in the systemic KI model. Also, similar to what was said above about the four SFs, the control function was mostly performed by the same actors that performed the four functions. Hence, at this level, the control function did not instantiate as a concrete separate subsystem, but is to be included in the systemic KI model.

When we follow Parsons, control at the level of the KI system as a whole would concern 1) the provision of knowledge, technology, and actors that the four subsystems would need to perform their function, 2) the governance of what and how to produce within the four subsystems, 3) the provision of services for the support of the four subsystems, and 4) measures to counteract the subsystems' inclinations to deviate from their function in the KI system (see Subsection 4.4.3). In the incidents, however, we found virtually no examples of the performance of such a control function. Since our focus in the critical incident interviews was on the performance of KI activities at the primary, technical level, this seems perhaps not surprising. However, considering that respondents reported broadly and extensively about KI in their companies, we still believe that the lack of examples here is somewhat surprising. Amongst the respondents were seven directors of high-tech SMEs. Since they have a controlling role in their company, we expected that especially they would report examples of the performance of the KI control function. This was not the case. However, there was another difference between the responses of these directors and of the engineers that were interviewed. This concerned the type of knowledge that they contributed to the KI system. While engineers' KI activities mostly concerned technical knowledge, directors' KI activities mostly concerned more supportive types of knowledge. Examples are Agrigen and Eltrode, where the director was responsible for knowledge about, respectively, markets and boundary conditions. These examples show that, while the specific knowledge to which directors' and engineers' KI activities refer are different, both have a role within the KI target system. From this discussion we can conclude that persons performing a control function in an organization (e.g., directors) do not automatically also perform a control function in a KI system. Rather, they perform KI activities themselves, and, as such, they also take part in the KI system at the primary level. The almost complete lack of examples of a control function at the KI system level does not necessarily mean that the control function does not take place at this level. As the exploratory interviews of Chapter 3 have indicated – in which the focus was more on management and control of KI than in the CIT interviews – there is a need for more control in the KI practice of NPD in high-tech SMEs. This suggests that control of the KI system is important for practitioners. Therefore, we conclude that a systemic KI model should include a control function at the KI system level.

Implications for the Systemic KI Model

As the discussions above have shown, based on the critical incidents, we believe that the systemic KI model should remain unchanged concerning its representation of the internal structure of a KI system. Hence, Figure 4.3 is proposed as the representation of this third structural characteristic of the systemic KI model.

5.4.4 Differentiated and Patterned KI Activities

In Subsections 4.4.3 and 5.4.3 we have proposed that a systemic KI model should consider SFs at one level (as subsystems of the KI system) and KFs at two levels (concerning knowledge from outside the KI system and concerning knowledge between subsystems). This implies that for the patterning of KI activities we also have to look at one level of SFs and two levels of KFs.

Knowledge Functions

Chapter 3 has demonstrated that KI activities do not pattern into KFs. However, it also has demonstrated that, for each of the three KFs at the two levels, KI activities are performed in practice. Also in the incidents that were reported, we found numerous instantiations of identification, acquisition, and utilization of knowledge at the two levels. Examples of identification of external knowledge are searching and browsing the Internet (all interviewees), visiting conferences (Clensco, Mediag), and proactive presentation by an external actor (Wax'em, Macman). Examples of acquisition are phone calls (Mediag, Clensco, Macman), analyzing samples (Devan, Mediag), downloads (Optimea, Nanomu), cooperative development (Devan), and visiting the source (Woodcoat). Examples of internal identification are asking a colleague (Mediag, Polycom) and browsing past projects (Polycom, Inventi). Examples of internal acquisition/transfer are invoking past experiences (Coamac), and informal discussions with colleagues (Polycom). Examples of utilization are application (all interviewees), calculating (Optimea, Eltrode), and testing (Woodcoat, Mediag). As we have found numerous examples of KFs in both the critical incident interviews and the exploratory study, we conclude that KFs do instantiate in KI activities in practice and thus should be included in the systemic KI model.

System Functions

Concerning the SFs, we could find examples of patterns of KI activities for each of the four SFs. These examples are summarized in Table 5.2. Because of the interview protocol, interviewees described much more goal attainment examples than any other function. Thus, Table 5.2 is not representative in terms of number of examples given for each of the four SFs.

Table 5.2 Examples of the four KI system functions

Adaptive function	Goal attainment function	Integrative function	Pattern mainten. function
Nanomu read articles it received from universities to stay informed about technological developments. Memaco was subscribed to popular scientific magazines and read them to stay informed. Macman received newsletters and e-mails to stay informed.	Optimea needed a new reflector for their microscope, searched the Internet, found it, ordered it, and installed it. Protinc received an order to develop a principle for separating waste materials, found a principle and designed a solution. Agrigen looked for a new market in South Africa and found it with the help of several sources of information.	Inventi changed its data structures from a project-based to a problem-based system. Clensco was implementing project management software to better store the company's knowledge. Polycom's employees met regularly outside the office to exchange knowledge in an informal way.	Protinc had drinks with a friendly physiotherapist that provides it with useful information. Mediag built relationships with core suppliers and wanted to maintain them for future use. Clensco had regular meetings with a network of companies operating in the same industry.

Rather than providing a representative set of examples, Table 5.2 provides examples that represent the diversity of the responses. For instance, for adaptive KI, the examples ranged from proactively staying informed (Memaco) to reactively waiting for information (Macman). For goal-attainment, the examples ranged from a very well-defined goal like finding and installing a reflector (Optimea) to a less defined goal like assessing whether South Africa would be an appropriate new market (Agrigen). For integration, we see that the examples range from relatively formalized systems (Clensco) to the informal meeting outside the office (Polycom). Finally, concerning the pattern maintenance function we saw examples ranging from the development of relationships in an n-to-n setting (Clensco) to the maintenance of a 1-to-1 relationship with a friend (Protinc).

Implications for a Systemic KI Model

Since there appeared numerous examples of each of the four SFs in practice, we conclude that SFs should remain an important part of a systemic KI model. Also, concerning that KI activities contributing to each of the KFs appeared in practice, also the KFs should remain included in a systemic KI model.

5.4.5 Interchange in a KI System

As we discussed in Subsection 4.5.2, KI interchanges consist of an interchange of knowledge for other knowledge or for generalized media. Concerning the 'knowledge part' of an interchange *between the KI system and its environment*, we believe we have already provided sufficient material that shows the necessity of including it in a systemic KI model: the whole notion of integrating external knowledge refers to this. The other aspects of interchanges

(interchanges between KI subsystems, and the 'generalized media part' of interchanges) are discussed in this subsection. With respect to the 'knowledge part' of interchanges *between KI subsystems*, we have found examples of all interchanges between the four subsystems. Hence, in total, we found examples of twelve interchanges. These are summarize in Table 5.3.

Table 5.3 Interchanges of knowledge between subsystems

From adaptive to goal attainment subsystem	From goal attainment to adaptive subsystem
By generally staying informed about new technologies, Devan found particular ideas for new products.	Polycom scanned the environment during a search for specific information. There was no time to do it separately.
By being receptive, Nanomu was contacted by an American company that wanted Nanomu to develop a new product for them.	During a search process Flunano always found information that could be useful for future purposes.
When Agrigen came across new relevant findings in the literature these were used for a new product.	During search for particular information, Mediag found a solution for a problem that it had had months before.
From adaptive to integrative subsystem	**From integrative to adaptive subsystem**
Macman stored some of the magazines it was subscribed to to stay informed in its own archive.	Flunano organized its bookmarks such that it could quickly scan for changes in information when wanted.
Mediag uploaded electronic catalogs and brochures of suppliers that it has received onto its intranet.	Based on earlier experiences, Coamac judged a certain fair too large to be useful for staying informed.
Coamac read magazines and newspapers and stored information that might be relevant in the future.	Since its employees possessed different knowledge, Polycom divided the responsibility to stay informed amongst its employees.
From adaptive to pattern maintenance subsystem	**From pattern maintenance to adaptive subsystem**
Woodcoat published about its new product to find new core and long-term customers.	One of Wax'em's core customers made Wax'em aware of a new potentially useful raw material.
Memaco informed everybody that it was looking for partners to establish a new company.	Eltrode's partners knew what is relevant information for Eltrode and informed it regularly.
Devan established a long-term relationship with a supplier that visited Devan to sell its materials.	To find new business opportunities Memaco talked with existing customers to generally find out what problems they had.
From goal attainment to integrative subsystem	**From integrative to goal attainment subsystem**
Inventi stored all information collected during past NPD projects in its archive.	In its projects Inventi reused knowledge of previous projects that was stored in their databases.
Optimea saved the outputs of specific search queries that were used into small spreadsheets.	Nanomu had books in its archive that were frequently used to find certain specific technological principles.
Flunano wrote down short summaries of particular findings to avoid the risk of forgetting them.	One of Coamac's projects failed because it was convinced that the internal knowledge was sufficient to design the solution.
From goal attainment to pattern mainten. subsystem	**From pattern mainten. to goal attainment subsystem**
Once contracted for a specific project, Eltrode tried to maintain a company relation for future cooperation.	Before searching for information widely, Wax'em first tried to find it at its partners.
After initial e-mail contact, Optimea developed a relationship with companies that were likely to help it now or in the future.	Agrigen talked a lot to its existing customers in order to specify exactly the products it should develop.
When a new information source outperformed previously used sources, Coamac switched.	In order to be allowed to use information of a certain source, Clensco had to subscribe to it for one year.
From integrative to pattern maintenance subsystem	**From pattern maintenance to integrative subsystem**
Since Mediag knew much about its partners it was easier to cooperate than to find new partners.	One of Eltrode's partners was responsible for most of Eltrode's knowledge about purchasing.
Once it was acquainted with a source of information, Woodcoat trusted this source and used it several times.	An employee of one of Optimea's partners transforms collected data into useful information.
Protinc found a new partner because its organized knowledge base enabled a direct understanding of the partner's problem.	A professor at the campus on which Polycom is situated, served as part of Polycom's organizational knowledge base.

As was the case for Table 5.2, this table is not representative in terms of number of examples, but rather should reflect the variety of the interchanges as they appear in practice. As we found at least three examples for the 'knowledge part' of each of the twelve types of interchange, we believe that these interchanges should be included in a systemic KI model.

We want to highlight two additional aspects of interchange between KI subsystems. The first concerns the notion that there should always be an *inter*change, implying that between two subsystems there is always a (direct or indirect) bidirectional interchange. Or in other words, there should be something in it for each actor. Subsections 2.4.2 and 4.5.2 mentioned a variety of generalized media that can be interchanged for knowledge. We assume that, in order to assess whether this second part of an interchange should be included in a systemic KI model, it is sufficient to show a few examples. Hence, we will not try to find instances of all media that were mentioned in the KI literature and in Parsons' theory. Neither will we try to show that the idea of interchanges holds for all 65 incidents (which would be hard anyway, since all incidents occur in a wider context where the indirect benefit of involved actors might be not mentioned in the incident). Rather, we will give two examples of how the lack of a balance can lead to problems. The first example concerns an interchange between a KI system and its environment. At Optimea, the director requested a sample of a product from another company in order to analyze it. However, the other company refused to send a sample because it wanted to avoid the risk that the interviewee would decide to produce the product himself rather than buying it. Hence, in this example the other company would not get sufficiently in return (e.g. a large order) for the sample he was asked to send. Another example, concerning the interchange between KI subsystems, is Clensco where people from marketing were asked to start filling a database with past projects but refused to do so. The most important users of this database were not the marketing people, but the engineers who wanted to use this database to have better access to the knowledge gathered in previous projects. Hence, while marketing people would need to provide input for the system, the engineers would receive most of its output. This could explain the refusal of the marketing people to provide input.

The second aspect that we want to highlight here is that interchanges can be direct and indirect. That is, actors can interchange via other actors. An example is Protinc where the director asked a personal friend to gather some relevant information when he would visit a number of stables. In this example, Protinc's director never visited the respective stables. However, he did acquire knowledge from them, via his friend. Another example is at Woodcoat where the director looked for the suppliers of his suppliers. In this example, Woodcoat uses its suppliers as intermediary between Woodcoat and the suppliers of the suppliers.

While the original concept of a system interacting with its environment is not very well able to model indirect interaction, the revised concept of system boundaries as discussed in Subsection 5.4.2 is able to deal with this. Figure 5.1 exactly showed this kind of interactions: the actors at the kernel of the system have no direct relation to the actors at the system periphery. Nevertheless, these actors at the periphery contribute to the system. Figure 5.1 also shows that actors may take a role as intermediary in the system: they bring the kernel of the system in contact with other actors that they have no direct access to. This going from one actor to another actor appears in virtually all the incidents. For example, engineers find something on a website, contact a company, get some new information, contact another company, etc.

Implications for a Systemic KI Model

From the discussions in this subsection we can conclude that the notion of a direct and indirect interchange between KI (sub)systems and between a KI system and its environment should be included in a systemic KI model. As the conceptualization of interchanges in Subsection 4.5.2 and the reconceptualization of system boundaries in Subsection 5.4.2 sufficiently cover this fifth characteristic of a systemic KI model, no additional modifications are needed.

5.4.6 Goal-Directedness of a KI System

Considering that KI activities are driven by goals of the actors that perform them, we believe it does not require additional argumentation that goal-directedness as such is an important aspect of a systemic KI model. With respect to the goal-directedness of a KI system we have discussed the type of goals, goal formulation, and the mutual effect of goal-directed KI activities. Below we will evaluate the necessity of including these aspects in a systemic KI model.

A first aspect of goal-directedness are the types of goals in a KI system. From the three types of origins (cognitive, affective, and situational) in all cases the KI process was guided by the situational goals. Although this might be because of a bias in our data collection procedure, we believe this reflects the situation as it is. Namely, it was mentioned frequently that there was no time available to reduce uncertainty or to fill a gap in an individual's knowledge (corresponding to affective, respectively, cognitive goals). For example, at Nanomu it was remarked that despite of not knowing why exactly a chosen solution worked (the use of a particular liquid to physically connect two layers on a silicon wafer), that solution was chosen because it worked and solved the problem. Also, it was said there that there is simply no time to read things that you find interesting but that are not directly useful for a particular project. Thus, situational goals seem to dominate the KI process in practice.

Does this mean that the cognitive and affective goals can be omitted from the systemic KI model? We believe not. Although these types of goals did not drive the KI process, they were certainly a limiting factor. For example, at Protinc it was remarked that before an engineer could actually try to solve a customer's problem he first had to achieve the right level of knowledge in the area of the customer, if only to be able to communicate with the customer about the problem. In this example, a cognitive gap is hindering the fulfilling of situational goals. Because of this importance of cognitive and affective goals in explaining the differences in outcomes of situational goals, we suggest a systemic KI model should include all three types of goals.

In the literature of Chapter 2 it was mentioned that goal formulation is an interactive process between at least two actors. This also was obvious in virtually all the incidents. Although interviewees started KI with a certain goal, this goal evolved during the subsequent KI process. For example, while the director of Optimea started with the goal to find out whether LEDs would produce a sufficient amount of light to function properly in a particular type of microscope; he ended up with ordering a particular type of high-efficiency LED combined with a particular type of reflector that together would produce a sufficient amount of light. Hence, based on what he found, Optimea's director constantly updated his goals.

Goal conflicts also appeared in many incidents. These mostly concerned goal conflicts between the source and the recipient and less between different parts of the KI system. An example of a goal conflict concerns a patent. While the owner of the patent developed it in order to protect knowledge, patents are an important source of knowledge for high-tech SMEs (e.g. Nanomu, Wax'em, Flunano, and Woodcoat). Another example is that when some interviewees requested a sample of a product to analyze it, the seller of the sample refused to send it because he wanted to avoid the risk that the interviewee would decide to produce the product himself rather than buying it (e.g. Optimea).

Concerning goal conflicts between KI subsystems we only have found indications that there is conflict between them because they ask for the same resources (e.g. time and money) and can therefore not always be satisfied. It also appeared that the goal-attainment function was most dominant, sometimes at the cost of other functions. For example, at Nanomu the dedication to problem solving went at the cost of the adaptive function since there was no time available anymore to build up general knowledge.

Finally, also the mutual effect of goal-directed KI activities appeared frequently in the incidents. The most frequently mentioned example was how the search for particular knowledge also led to finding knowledge that was relevant for other purposes. For example, while searching for and finding a certain cartridge, the director of Flunano also discovered that there were three types of cartridges. Whereas he could not use this knowledge at that moment he indicated it could be useful for later purposes. In the incidents it appeared that sometimes the interviewees explicitly took account of unintended consequences in advance. An example is Protinc where an NPD manager explicitly did not make personal contact with another company but looked for information on the Internet in order to keep the other company ignorant of his interest.

Implications for a Systemic KI Model

Given that, in the critical incidents, examples have been found of all the aspects of goal-directedness as they were mentioned in Subsection 4.6.1, we suggest that the conceptualization of goal-directedness as presented in that subsection should remain unmodified in a systemic KI model.

5.4.7 KI System Evolution

The final system characteristic concerns the learning of the KI system. Subsection 4.6.2 distinguished the following types of learning: functional learning (for each of the four SFs), interfunctional learning, and learning of learning (deutero learning). The following examples of the incidents show whether and how each of these types occurred in practice.

Firstly, we consider the four types of functional learning. An example of learning during adaptation is at Flunano. In the past, the director of Flunano went to all the conferences in his field to stay informed. However, since recently he is not doing this anymore. He now feels he knows all the important players in the field and does not need to visit these conferences anymore. Hence, he has changed the way the adaptive function is performed. Another example is at Memaco where in the course of time the director has found out, that although they cost a lot of money, it is worthwhile to subscribe to popular scientific journals to stay informed. In this case, both examples show how the adaptation function has been adjusted in the course of time.

An example of learning during goal-attainment is at Protinc, where an NPD manager had developed a portal that allowed him to improve his searching activities. On this portal he has – amongst other things – collected relevant links and created a meta search engine that queries his most relevant databases. This portal has substantially changed and improved his way of searching for useful information on the Internet. Another example is how engineers at Inventi, Polycom, and Devan in the course of time have developed – independently from each other – the heuristic that if amongst the first ten hits of the Google search engine there is no relevant result, then they must have used the wrong keywords. Both examples show how goal attainment processes have been adjusted based on experiences.

An example of learning during integration is at Agrigen where the director has learned that some types of knowledge are less volatile than other types of knowledge and that it is only useful to store knowledge that is not volatile. Similar heuristics were developed at Nanomu and Flunano ('scientific knowledge is less volatile than many other types of knowledge and thus it is worthwhile to store it). Also these examples show how a KI function has been changed in the course of time.

An example of learning during pattern maintenance is the development of a heuristic that it is better to first ask existing contacts before establishing new contacts, for example because it requires much effort to build trust in a new contact (e.g. Woodcoat, Mediag). Another example is at Flunano where the director has discovered that there seems to be a maximum amount of contacts that he can maintain. This has led him to change his behavior from establishing contacts to maintaining or even breaking contacts. Again, both examples show a change of this function.

Secondly, it was already remarked before that there are interchanges between the four subsystems, meaning that the output of one subsystem is used as an input for another subsystem. As suggested in Subsection 4.6.2, this also applies to learning: subsystems can learn from other subsystems. An example of such interfunctional learning is at Clensco, where an NPD manager realized during the execution of new projects (goal attainment function) that there should be something improved in the way past projects are stored in the organization (integrative function). Another example is at Flunano, where in the past they stored a lot of software documentation (integrative function), they do not store this anymore because, whenever a problem arises, they can find the required information on the Internet (goal attainment function). A final example is at Inventi, where in the past its engineers went to existing partners to find specific knowledge they needed (goal attainment function). Today, with the Internet, it is much easier for them to look for specific knowledge beyond their existing partners. As a result Inventi is less loyal to its existing partners (pattern maintenance function).

Finally, while there were numerous examples of functional and interfunctional learning, considering the learning of learning (deutero learning) we have found no examples. From this we could conclude that deutero learning should be omitted from the systemic KI model because it does not occur in practice. However, we have to be careful with such a conclusion, because the lack of examples of deutero learning might be a result of our chosen methodology. As we also have argued in Subsection 5.4.3, in the interviews we asked for examples of KI, not for examples of control or learning. As also argued there, respondents reported broadly about KI, which makes that we believe that the lack of examples here is still somewhat surprising. Also, while there are no examples of deutero learning, we have found numerous examples in the 65 incidents and the preliminary interviews of a *need* for deutero learning. We already mentioned the calls for more structure and overview (see Chapter 3) as an indicator of this need: people are aware that KI is not optimal in their organization, but they do not know how to improve it. In other words, they want to improve their control function. Finally, in the 65 incidents we observed that the four types of learning mentioned above were often unintended or implicit consequences of KI activities rather than intentional consequences, which is another indicator of this need. Hence, we believe that deutero learning should be modeled in a systemic KI model. This is further explained in Subsection 5.5.7.

Implications for a Systemic KI Model

This subsection has provided examples of functional learning and interfunctional learning. Although there were found no examples of deutero learning, we suggest that each of the types of learning (functional, interfunctional, and deutero learning) should be included in a systemic KI model

5.4.8 Conclusion on the Manageability of the Model

By confronting the systemic KI model of Chapter 4 with 65 incidents of KI in practice this section has evaluated the complexity part of the manageability of the model. We have particularly sought for possible simplifications of the model in order to make it less complex – and thus more manageable. Also, the examples that were given have made the model more concrete and precise with respect to its use context, which also improves its manageability. As a result of this exercise the following adjustments have been suggested:

1. Actors' roles have been simplified by omitting their role as professional.
2. Instead of the notion of system boundaries it was suggested to use the notions of interaction density and barriers between actors in the system. Together, these notions provide a gradual and dynamic way of distinguishing systems from their environment. While this is not so much a simplification of the systemic KI model, we deemed it a necessary adjustment to make the model more congruent with KI in practice.
3. It was highlighted that the new conceptualization of system boundaries also provide a better means to model indirect interchange and chains of interchanges between subsystems and between a KI system and its environment.

We believe that although our aim was to reduce the complexity of the model, we have not been able to do so. Rather, by changing the notion of system boundaries, we might even have made the model more complex. What is important, however, is that we have now assessed whether the model could be made less complex. The answer thus seems negative. But we have made the model more manageable in another sense; that is, by providing concrete examples of the abstract notions of Chapter 4 and by better adjusting it to the context of KI in high-tech SMEs. The next section will show how the adjusted model can be useful in practice. Furthermore, in Chapter 6 we will return to the two other aspects of manageability: understandability and the form in which the model is instantiated.

5.5 Results: Fit with the Problem of the Systemic KI Model

After an evaluation of the manageability of the model in the previous section, this section will evaluate the model's fit with the KI problem. As discussed in Subsection 1.3.1, the targeted contribution of the model concerns the improvement of KI problem solving. As argued there, the model should lead to the identification, explanation, or solution of KI problems that without the model would not have been identified, explained, or solved. To evaluate to what extent the model supports this, we believe that it is again useful to go through each of the structural, behavioral, and control characteristics of a systemic KI model. In the following subsections we will evaluate the model's fit with the problem for each of the seven characteristics by providing a number of examples from the 65 critical incidents. These examples are demonstrative rather than exhaustive.

5.5.1 Elements of a KI System

The recognition that a system consists of several types of elements introduces at least two interesting types of choices for managers. The first concerns that system elements can substitute one another, the second concerns that system elements can be complementary. Both can be illustrated by the following detailed example of Eltrode.

Eltrode is a small, five-year-old, development and engineering company in the Netherlands that develops electronics and embedded software for control and operation systems. The company employs one director and six engineers. In addition to designing products and solutions, Eltrode offers project consultancy to assist in customers' product development. Although not exclusively, many products and prototypes designed by Eltrode are produced by its sister company Elpro, usually in small quantities for specific customers.

According to Eltrode's director Harry Eastman, a typical example of KI in his company concerns the case of a defective printing machine owned by Printco. Printco is a medium-sized printing company, printing brochures and books in small runs. For its printing activities, Printco uses a printing machine built in 1982. It had operated perfectly for many years but suddenly the machine ceased working. Printco had contacted the supplier, who told them that the operating system was defective and could no longer be repaired or replaced since components were out of production and out of stock. Since the machine had always worked well, Printco decided to approach Eltrode, explain the problem, and ask them to repair the printing machine's operating system. Harry received this request and submitted an offer which was accepted by Printco. Consequently, Printco sent the defective printed-circuit board to Eltrode, where three engineers started to analyze it. By deconstructing the complete board and testing all the components separately they deduced what their function was, and which was defective. Next, using their bookmarked websites, they searched for a replacement component on the websites of previously contacted component suppliers in Germany, Asia, and the US. Once they had selected a number of candidate components they started to work together. While Sally was searching the specifications of these potential replacements and downloading the datasheets, Peter was testing the board, and George was calculating how Peter's test results compared to the component specifications that Sally had found. Based on their joint effort they selected the best component. Next, since Elpro carries out purchasing activities for Eltrode, Harry gave Elpro an order to find out where to buy the specific component from and to go ahead and buy it. Elpro bought the component from a US company and sent it to Eltrode, where Sally soldered it, together with the other components, back onto the printed-circuit board. Finally, Harry sent the repaired board back to Printco, which is now again using its 1982 printing machine.

When we consider this example using the systemic KI model, we can first observe that the model can be used to find substitutes for particular elements. Concerning the roles of actors in the example given above, we observe that Harry served as the representative of Eltrode and did all the communicating with Printco. As the company's director, Harry is an expert in marketing and management. However, he was not able to fully understand and communicate specific technical details about the problem at Printco. As a consequence, Sally, George, and Peter had to spend a lot of time on deconstructing and testing the printed-circuit board. Perhaps, if they had talked directly to Printco, they might have found out earlier what the exact problem was. If they (or one of them) had talked to Printco themselves this would have meant that Harry would serve as a marketing specialist rather than as the representative of Eltrode, and that Sally, George, or Peter would have talked to Printco as a technology specialist. This could have improved the KI process.

Concerning the technologies that were used in this example, we see that Eltrode has used information technologies (i.e., a computer to search the Internet) and non-information technologies (i.e., testing equipment, soldering iron) to perform KI activities. In this example, the KI model might help to find alternatives for these technologies, or to use technologies in a different order. In this case, Eltrode first used technologies to decompose the printing circuit and find a defective component after which it used a computer to find this component. Alternatively, Eltrode could first have looked on the Internet for a working printing circuit (e.g. in a second-hand still working printer) and consequently install this printing circuit in Printco's printing machine. Although buying the second hand printer would probably be more expensive than buying the component, this alternative approach could have saved a lot of time.

When we consider the KI activities, we see that, in the example, not all the KI activities that were mentioned in Subsection 4.4.1 have been used. This implies that there may be unexplored alternatives. For example, when searching for alternative components, Eltrode only conducted a focused search strategy, assuming an analyzable environment. Insofar as Eltrode chose to refer to known component suppliers, this strategy seems the most appropriate. However, Eltrode did not look beyond their known suppliers to perhaps find a better solution. Thus, for example, browsing as an alternative strategy might have produced better results and thus could have improved the KI process. We will discuss KI activities in more detail in Subsection 5.5.4.

Finally, concerning the carriers of knowledge that are used in the example, we see that there is much emphasis on non-information technologies. Eltrode's engineers immediately started to analyze the defective printed-circuit board and were looking for suppliers of the defective component. Although the output indeed had to be a non-information technology (the printing machine should function again), Eltrode could have used more knowledge residing in information technologies and actors. For example, rather than only searching websites of known suppliers to find an alternative component, Eltrode also could have searched for knowledge from other companies or interest groups to find out whether the problem with the printed-circuit board has occurred before, or even had been previously solved. Again, KI could have been improved if Eltrode had looked for alternatives.

The complementary nature of the elements of the KI system suggests that KI could not only be improved by substituting some elements by other elements, but also by better tuning the various elements of KI. An example concerns the fact that Sally, George, and Peter solved the problem together, as a team. While each of them is a qualified engineer, they each have specific strengths. Sally is better at searching the Internet, Peter at testing the printed-circuit board, and George at calculating. The awareness that perhaps only by combining these individual qualities the problem could be solved in the given period provides Harry with a better means to assess the importance of his individual engineers for the company. This can help Harry, for example, when he wants to hire or fire an engineer.

Another example is the complementary nature of KI activities. In the example above, Harry acted as Eltrode's representative in communicating with Printco. The suggestion above, to improve this KI process, was that Harry could have instead acted as a specialist. However, even if Harry were to keep his role as Eltrode's sole representative, the KI process could be improved by better tuning his knowledge acquisition to the knowledge required by Sally, George, and Peter. This could be achieved by better knowledge diffusion within Eltrode, for example by regular e-mail contacts or shared coffee breaks.

A final example concerns the observation that knowledge resides in each of the elements of a system and in their interrelations. In the example, we see that Printco, Eltrode, and Elpro are specialized in respectively printing, product development and consulting, and production. We can ask why, for example, Printco asked Eltrode rather than trying to solve the problem by itself. One likely answer is that the knowledge required cannot easily be acquired. Eltrode possesses a system of actors (Sally, Peter, George, Harry), technologies (e.g., computers, testing equipment), and knowledge (e.g. skills, bookmarks, and experience) that allows Eltrode to solve the problem probably quicker and better than Printco would be able to do. For Eltrode, it seemed rather easy to acquire the additionally required knowledge (a supplier of the defective component). This example shows us that the awareness of the systemic nature of knowledge can help managers in deciding what to do within the company and what to outsource.

In these examples, an analysis of KI with a KI model that would not show the exchangeability and complementary nature of system element would have provided Harry Eastman with inadequate conclusions and considerably less ways to improve the KI process at Eltrode. For example, such a model would not explain that the situation that Sally, George, and Peter had to completely deconstruct the printed-circuit board could be caused by Harry, since in his role of company representative he did all the communication with Printco.

Rather, such a model would probably exclude Harry from the analysis of KI, and give less opportunities for improving KI.

5.5.2 Boundaries of a KI System

In Subsection 5.4.2 we have suggested, using the metaphor of a city, to replace the notion of a system boundary by the notion of interaction density and barriers. Perhaps the most important contribution of the notion of a system boundary (and also of interaction density and barriers) is that system boundaries can be managed. They are not fixed and not necessarily similar to organizational boundaries. For high-tech SMEs this helps to realize that the environment is not constructed of only organizations but also of parts of organizations and loose elements. It also helps to realize that these (parts of) organizations and loose elements can be considered as part of the system while other parts of the high-tech SME can be considered as part of the environment.

When we look at the 65 incidents, we believe that practitioners are already aware of this and also use this awareness to manage KI. For example, the director of Flunano remarked that he did not need to talk to directors or marketing people of another company. Rather he wanted to talk to people of the R&D department. Hence, he only needs the R&D part of another organization. Additionally, the directors of Devan and Optimea remarked that they often use knowledge from individual hobbyists that published something on the Internet and that they were looking for particular individuals in a large organization. Hence, they looked for individuals rather than organizations. Additionally, the director of Optimea cooperated so intensively with somebody at a partner company that this person was almost considered as an employee – and as part of KI the system (the same can happen, for example, with interim jobs or freelance jobs).

When practitioners are already seem aware of the flexibility of system boundaries, the question arises what this characteristic of a systemic KI model can add in practice. Our first answer is that it is helpful if only because this flexible notion of a system boundary fits better what happens in practice than the traditional concept of system boundaries. Hence, practitioners might feel more comfortable in using this flexible notion of system boundaries. Additionally, we will give a number of examples of how this notion could be used to improve KI practice.

The first example concerns the idea that a KI system can cross organizational boundaries. In several incidents, (e.g. Nanomu) it was remarked that companies' websites are usually developed by the marketing department of that company. Let us call it company A. Hence, from this perspective, the website is considered to be part of the sales function of company A. Alternatively, the engineers at Nanomu use this website in their product development to gather relevant information. For this purpose, they require very different information than they would when they were interested to buy something of company A. For example, for product development they need more technical details. This suggests that this website functions in two different types of systems: the sales function of company A and the NPD function of Nanomu. Alternatively, when we approach this from the perspective of a KI system, we can observe that this website also can be seen as a facilitator of a KI goal attainment system. Nanomu needs particular information from the other company in order to develop its products. Alternatively, company A is interested in cooperative product development. Hence, when it is realized that a corporate website is part of this KI system, this can lead to changing the website, for example, by including more technical details in order to facilitate cooperative NPD.

A second example concerns the flexibility that people have in crossing system boundaries. The idea that there is no single type of boundary but that there are barriers, creates more flexibility in the interaction between a system and its environment: a boundary means that it should be crossed; a barrier also can be avoided. An example is Agrigen, where the director was looking for opportunities to expand the market to China. In order to acquire necessary information he first tried to search the Internet. Because this was rather unsuccessful he proceeded by going to China for a trade mission. This yielded somewhat better results but he was still unsatisfied. Back in the Netherlands he decided to send a Chinese woman who was currently working in the Netherlands. This was more successful. In this example we see that in order to avoid the language barrier, Agrigen's director had multiple options. The first option that he used was switching between two types of media. Although he had a preference for the Internet, he afterwards decided to visit China. When this did not work either, he switched from doing it himself to outsourcing the task to a Chinese woman by sending her to China. An alternative would have been to ask the Chinese woman to query the Internet for him. When confronted with this alternative, the director of Agrigen said that he simply had not thought of it and that that would actually have been the best step. The potential added value of the systemic KI model in this case is that an explicit recognition of the multidimensionality of the barrier could have led Agrigen's director to choose for the last option, which he would have preferred.

A final example concerns the case of the incorporation of part of the environment in the system. For example, consider the case of Polycom. Polycom is a three year old small chemical company located in a university building. The main expertise of Polycom's five employees is in the field of polymers. Using this expertise they develop polymer solutions for their customers. When the engineers need to know something about a particular polymer, they regularly consult a specific professor at the university. They can ask him about whatever problem, and he knows which polymer would be suitable to solve that problem. Currently, this professor is consulted as an external advisor and thus considered as being external to Polycom's KI system(s). Since they consult him for a particular goal, this professor mainly serves the KI goal attainment system. Alternatively, when Polycom would have seen (or made) the professor part of its KI system(s), his contribution could have been substantially higher. Having a tremendous amount of knowledge about polymers, this professor also could have served Polycom by supplying general knowledge about polymers. This would imply that he had a role in Polycom's adaptation function. An example of this would be the professor regularly presenting the latest trends in polymer research to Polycom. Also, because of his broad knowledge in the field, the professor would have been very suitable to see connections between several of Polycom's projects. As such, he could serve Polycom's integrative function. This could take place, for example, by inviting the professor for working lunches. Hence, we believe that Polycom could have benefited more of the professor when it had explicitly considered the professor as part of Polycom's KI system(s).

5.5.3 Internal Structure of a KI System

In Subsection 5.4.3 we have argued that concerning the internal structure of a KI system, the systemic KI model should remain unchanged. Hence, it should include four SFs, three KFs at two levels, and a control function at two levels. Below we will provide a number of examples of how a systemic KI model that provides this structure can be helpful in practice to identify, explain, and solve KI problems.

A benefit of distinguishing SFs is that managers in practice can subdivide the KI problem into several parts, which makes KI problems easier to deal with. We can illustrate this with an example. Consider Clensco, which is a fifteen year old manufacturer of chemical lubrication and cleaning materials, employing 35 employees. In the past years, Clensco has more and more faced the problem that they had to reinvent the wheel. In their new projects, they realize that they have done similar projects in the past but they cannot invoke these projects, simply because there are no records of it. There are some ring binders that contain information about some materials that were used in these past projects, but these do not contain much information about the projects themselves. What is missing is, for example, the purpose of the material in the project and the order in which things have been tried. As a solution for this problem, the management of Clensco has decided – after requests of R&D and in cooperation with the marketing department – to implement a project database. This database should contain the kind of information that is currently missing, in electronic format. Currently, there is however the problem of who is going to provide input for the database. The R&D department needs the database most to reuse ideas of old projects. According to the interviewee, the marketing department should take the initiative and steer the input of the database, since they initiate the projects. Until now, the marketing department has however taken no initiative. Hence, there is the problem of an unused database on the one hand and still undocumented projects on the other hand. When we analyze this example from the perspective of SFs, it appears that in the current situation the R&D department and the marketing department are part of different KI subsystems (i.e. R&D is responsible for using the information in a specific project, which can be considered as the goal attainment function, and marketing is responsible for the input of the system, which can be considered as the integrative function), while the implementation of the project database assumes that they are part of the same KI subsystem. By decomposing the problem into a goal attainment function and an integrative function, Clensco can now try to find solutions for the problem. For example by considering that both subsystems need to benefit from the project database. Since this concerns the interchange between systems, this is further elaborated upon in Subsection 5.5.5.

We can give a similar type of example for the KFs. When it is realized that identification, acquisition, and utilization of knowledge are different functions, the problem of KI can be split into smaller parts. An example is Flunano where the director wanted to acquire knowledge by analyzing a number of patents. In order to do so he operated as follows. The first thing he needed to do was to find relevant patents. For this he used the online patent database of Espacenet. After browsing and searching a while he had selected 25 patents that seem to be relevant. Next, he wanted to print these patents. However, at that time, Espacenet only provided the opportunity to print each patent page by page. The director considered this too much work, and with the 25 patents he had selected he went to the online Delpion patent database, where he could buy them complete for about three dollars each. Once received, he could print them and analyze them. This example shows how the identification of patents is different from their acquisition. Flunano uses a completely different source for both, hence showing that the two functions are not necessarily connected to a single source. As such, this example shows the usefulness of explicitly distinguishing the three KFs as it is suggested in the systemic KI model.

A second benefit of structuring a KI system into SFs is that a decomposition of KI into several SFs allows managers to set priorities. That is, at a given point of time they can decide to put more emphasis on one SF than on another SF. It was already remarked that in most of the incidents, the focus is on the goal attainment function, implying that there was made an implicit or explicit choice to focus on this kind of SF. We also have seen cases where this went at the cost of other SFs. For example, at Nanomu it was reported that because of the emphasis on goal attainment (i.e. solving particular problems) there was no time for adaptation (i.e. reading relevant and interesting publications that are not directly relevant for solving an actual problem). When it is assumed – as it is in system theory – that each of the SFs is important for a well-functioning system, an explicit recognition of the lack of time for the adaptation function, might Nanomu's director make to allow its engineers to spend more time on reading. Related to this is the recognition that the four SFs concern different criteria for organizational effectiveness. While goal attainment strives for productivity, adaptation strives for value creation and utility of resources, integration for coordination, and pattern maintenance for continuity (see Subsection 4.4.3). By recognizing these differences, managers can decide, for example, at a certain moment to focus on productivity, while at another moment they can decide to focus on continuity, dependent on the need at that time.

The same holds for the KFs. When we consider that for effective KI, each of the KFs needs to be performed, this might, at a certain moment, lead to the decision to spend more effort on one KF and less on the other. An example is Agrigen which spends a lot of effort on identifying and acquiring new gene structures and their behavior and on storing them in a corporate database. On the other hand, little effort is spend on using the knowledge from this corporate database. While the creation of such a database could be a goal in itself, the knowledge stored in this database could be used for additional purposes. When Agrigen would have recognized this, it could, for example, have put more emphasis on the utilization of knowledge than on the identification and acquisition. This example shows how explicitly distinguishing the utilization function from the identification and acquisition function, can help practitioners to put different priorities.

Finally, the explicit distinction between a controlling organ and a target system in the systemic KI model can help managers in practice to decompose a KI problem into smaller parts. When KI problems appear, this distinction can help them, for example, to find out whether it is the goals that are the problem, or the KI activities that should contribute to these goals. While it may be natural for them to make this distinction in their business activities, we believe it is not so natural for them to do this for KI. An example is at Nanomu, where a customer asked Nanomu to develop an optical light switch. This customer had promised its private investors that it would develop such optical light switch itself. However, since it was not capable of developing such a switch itself, it asked Nanomu to do it. Engineers at Nanomu went to search in the scientific literature and on the Internet whether it would be possible to develop such a switch. After a while they found a very innovative way to develop the switch. While the engineers were thrilled about the technological advanced solution they found, the customer did not like the solution. They found it too hazardous and believed they could not sell this idea to their investors. They wanted a more conservative solution and stopped cooperation with Nanomu. When we analyze this example from the distinction between a CO and a TS, we see that the TS has performed its function: given the goal of finding a solution, the engineers did a successful job. However, the fact that this solution was not accepted by the customer suggests that the goals that were set in this example were perhaps not the right goals. While the goal was defined as to find *a* solution, a more appropriate goal would have been to find a *conservative* solution. When Nanomu would have explicitly considered the distinction between a CO and a TS in this example, this might have either saved a lot of wasted time or led to a solution that would be accepted by the customer.

5.5.4 Differentiated and Patterned KI Activities

In Subsection 5.5.3 we discussed the structure of the system and highlighted the usefulness of distinguishing several functions of a KI system. In the current section we highlight the usefulness of distinguishing these functions because of their relation with the KI activities that are performed in order to contribute to these functions. Hence, we open up the black box of these functions.

Firstly, the equifinality of functions suggests that there might be interchangeable KI activities to realize a particular function. In the example of Eltrode and Printco in Subsection 5.5.1 we already gave one example of the interchangeability of KI activities (i.e., alternative ways of identifying external knowledge). An additional example of how the recognition of the interchangeability of KI activities for the performing of particular functions concerns Protinc, where one of the engineers has developed a web portal to improve the search for chemical information on the Internet. On this portal you can search for specific chemical knowledge, you can browse a number of websites, and you can receive the latest chemical news. Hence, this portal supports at least three alternative ways of knowledge identification. The fact that this portal is, according to its developer, worldwide one of the most used website providing (access to) chemical information, seems to indicate that the explicit offering of alternative ways to perform a particular function is appreciated in KI practice. Hence, from this we conclude that this aspect of a systemic KI model is useful in practice.

Secondly, the patterning of KI activities into SFs suggests that KI activities are complementary. Here we can take the example of the goal attainment function. As indicated in Subsection 4.5.1, goal attainment consists of the identification, acquisition, and application of particular knowledge for a particular purpose. As these KI activities together form the goal attainment function, goals are not attained if one or more of them are missing. This means, for example, that despite of the identification and acquisition of a large amount of useful knowledge, goals are not attained if this knowledge is not utilized for the particular goal. This can help managers in practice to realize that it is sometimes more beneficial to improve the utilization of knowledge than its identification or acquisition. An example of how the three are interdependent is at Coamac, where an NPD manager needed a new component for the development of a new coating machine. He might have been able to identify exactly the component he needed for the development of that machine at a manufacturer in the US. Also, he might have acquired all the relevant specifications in the form of documents. However, this is only useful when he also would have been able to acquire the physical component. By taking this acquisition and utilization problem into account beforehand, he has limited his search to potential suppliers in the neighborhood. This example shows how recognizing that several KI activities are patterned helps to realize a particular KI function.

Finally, patterning also means that KI activities are not exclusively dedicated to a particular function (otherwise it could have been called, for example, attribution). This implies that a single KI activity can contribute to more than one KI function. An example is doing a literature study. In general, this can be considered as contributing to the adaptive function: a literature study provides general knowledge in a certain field. However, at Nanomu, there was an example of where a customer requested for a literature review. In this example, the literature review has become part of the goal attainment functions. A similar example is at Inventi. Since Inventi is an engineering bureau, it does not produce any products itself. Rather it develops reports for its customer. While the development of reports would usually be considered as part of the integrative function, in this particular case it is part of the goal attainment function. When managers are aware of which function a KI activity contributes to, this can help them in choosing alternatives for that KI activity and in patterning that KI activity (connecting it to the other KI activities belonging to that function).

5.5.5 Interchange in a KI System

The preceding subsection highlighted the usefulness of the internal coherence of KI functions. In addition to this, the current section highlights the usefulness of recognizing the interchanges between them.

A first way in which it can be useful to consider interchange between KI (sub)systems is by realizing that interchanges should somehow be balanced. This suggests that whenever someone provides input, he also should receive something in return. Subsection 5.5.3 has given the example of the implementation of a project database at Clensco. It was remarked there that it could be helpful to analyze this problem by splitting it up in a goal attainment function and an integrative function. Using the notion of interchanges we can now extend this analysis and find a possible explanation of why the people from marketing (representing the integrative function) did not want to provide the required input for the database: they did not get something (or at least not enough) in return for their contribution. A possible solution would be to make sure that the marketing people do get more in return for their required contribution. This can be a direct return from the goal attainment subsystem (e.g. the engineers provide input to the system that is relevant for the marketing people) but also an indirect return from, for example, the adaptive subsystem (e.g. marketing people might get access to new issues of magazines only if they provide the required input for the database). The latter solution may sound contradictory: if these magazines are there, why not give everybody access to it? However, when seen in the light of the full KI system, this solution might make sense, since it provides a way to steer the behavior of the marketing people at the benefit of the integrative function. As this example shows, KI functions are interdependent. There can be direct interchanges between two subsystems but also indirect interchanges which involve additional subsystems. The interchanges between subsystems show that changing one subsystem affects other subsystems, that subsystems are dependent on the outputs of other subsystems, and that a seemingly counter-effective measure might in total have a beneficial effect for the KI system as a whole. For managers, realizing this provides a means to steer and mutually adjust KI subsystems.

Another way in which it can be useful to consider the interchanges between KI (sub)systems is that it helps to realize that there are different types of interchanges. Interchanges can instantiate in the form of actors, technologies, and activities (the knowledge carriers of a KI system). As discussed in Subsection 5.5.1, these elements can be seen as substitutes and as complements. The fact that there are alternative ways of interchanges suggests that managers can make a choice between the elements. The fact that they might be complementary suggests that this choice should be made carefully. Since Subsection 5.5.1 already elaborated on the fact that elements substitute and complement each other, we will not further elaborate on this here.

A final example of how the idea of interchanges between (sub)systems can be useful in practice is by considering the number of interactions. On the one hand this refers to the number of interactions between two actors; on the other hand it refers to the number of actors involved. An example where considering the number of interactions is helpful is the already mentioned example of Agrigen, where the director sent a Chinese woman to China to do the communication over there. In first instance, the director directly tried to communicate to a number of persons in China. For the director this required a lot of interactions, both because he had to communicate with a number of persons and he needed a lot of communication in order to understand them. This was without much success. When he sent the Chinese woman, he substantially reduced his amount of interaction: he only needed to communicate directly with the Chinese woman, and he could do it in a language he mastered which required less interaction between him and the Chinese woman. In this example, the Chinese woman served as an intermediary between Agrigen's director and the Chinese persons. Other examples of the use of intermediaries in order to reduce the number of (potential) interactions are numerous. Particularly on the Internet we see this quite often, for example to query a large number of suppliers at once (Devan, Macman), or to query a large number of journals (Nanomu, Woodcoat). The explicit distinction between the number of interactions between two actors, and the number of actors to interact with can also help to explain why intermediaries are used frequently for identification purposes but less frequently for acquisition: for identification there is a large number of potential sources to interact with; an intermediary can effectively reduce this number. However, once a relevant source is identified it might need more interactions to communicate with the source via an intermediary than by directly communicating to the source. This extra interaction is needed, for example, because the recipient has to interpret the messages from the intermediary, which, in turn, has to interpret the messages from the source. By inserting the intermediary in between the source and the recipient, the clarifications of the possibly distorted messages might require additional interaction.

5.5.6 Goal-Directedness of a KI System

While the previous five subsections have focused on the structural and behavioral characteristics of a systemic KI model, this and the next subsection concentrate on its control characteristics. In this subsection we will use a number of examples to highlight the usefulness of the goal-directedness characteristic of a systemic KI model.

A first way in which this characteristic of the model is useful concerns the type of goals. As we have discussed in Subsection 4.6.1, the model distinguishes three types of origins: cognitive, affective, and situational needs. In order to illustrate the need to include cognitive and affective needs in the model, Subsection 5.4.6 provided the example of an engineer at Protinc who could only try to solve a customer's problem after he had achieved the right level of knowledge in the area of the customer. Cognitive and affective goals (or needs) also help to see why it is easier for someone to operate in a known field than in a new field. While the situational goals might be identical, affective and cognitive gaps will be much larger in a new field. An example at Protinc is how an engineer had to find a solution to separate specific waste materials from a larger amount of waste materials. After a lot of analysis and thought he got the idea that this should be possible with a liquid in which the heavier particles of the waste material would sink, while the lighter particles would float. He had never seen something like that before and he had no idea whether such liquids existed or not. As he could determine the density of the particles, he knew what density the liquid should be. Hence, he went to search the Internet for a liquid with that density. After a long search he found out that there is an industry specialized in developing 'float-sink liquids' which could deliver the type of liquid the engineer would need. In this example, it took the engineer a lot of effort to find a solution for the NPD problem because he was unaware of an industry producing float-sink liquids. Had he known this before, the solution to the NPD problem would have been easy to find. This example shows how cognitive, affective, and situational needs are interdependent when striving for particular goals. This recognition can help managers to realize that, for example, achieving a certain level of knowledge, reducing uncertainty, and solving a problem are goals with a very different origin (i.e. cognitive, affective, and situational needs). This also can imply that rather than focusing on situational needs it might sometimes be more desirable to take into account cognitive and affective needs. An example is to teach persons how a particular industry is organized before letting these people develop a new product for that industry.

A second way in which this characteristic of the model can be useful concerns goal conflicts. There were a number of incidents where it appeared important for the recipient of knowledge to take into account the goals of the source of knowledge. One example is at Memaco, where the director has scanned several companies for potential cooperation. In order to assess whether a company is interesting, he needed information like the number of employees and the turnover. He explicitly remarked that although companies might provide this information on their websites, he had to be very careful in believing them, since they had an interest in exaggerating these figures. Their goal might be to grow or to create as many partnerships as possible, while his goal was to find a reliable partner. What he did subsequently, was checking this information at a source that would have an interest in providing the correct figures, for example the chamber of commerce. While in this example, the director had explicitly considered the goals of the source and the potential conflicts between his and their goals, there are similar examples where this was not considered. For example, at Protinc and Agrigen it was remarked that it is very difficult to get financial information from companies. However, they only considered the companies themselves as sources of information. When they would have realized that although companies might have an interest in not providing this information, there are other sources that do have an interest in providing the correct information, they could also have turned to, for example, the chamber of commerce where this information is available for free or at low cost.

A final way in which we will illustrate the usefulness of this characteristic of a systemic KI model concerns the unintended consequences of KI activities. An example is at Woodcoat, which is a coating manufacturer with about 20 employees and a history of over 100 years. As an engineer, Woodcoat's NPD manager is constantly looking for new products to use in its coatings. It happens quite often that potential suppliers proactively send their products to Woodcoat. In the past, the NPD manager found this great: he did not have to look for the products, since they were sent to him! He tried the respective products and reported back to the suppliers whether this was what he was looking for, and if not, what was wrong with it. In the course of time, however, he has become less enthusiastic about this. He noticed that in some cases, suppliers did not send him products in order to sell them, but only to let Woodcoat experiment with the products and to receive their comments. In this example, Woodcoat's NPD manager analyzed the products of potential suppliers in order to find out whether these were useful to him. As an unintended (and unwanted) consequence, however, he in the meanwhile also generated knowledge for the supplier. This example shows how a realization that KI activities can contribute to multiple goals and can lead to unintended consequences can lead actors to reconsider the way they perform KI.

5.5.7 KI System Evolution

The final characteristic of a systemic KI model concerns the evolution of the KI system, which also is referred to as the learning of the KI system. By demonstrating in the six previous subsections how the model can be used to improve the other system characteristics, we have, in fact, also demonstrated its usefulness for learning. More precisely, by showing how the model can be used to improve KI functions and their interrelationships we have respectively demonstrated the usefulness of the model for functional and interfunctional learning. We believe that, since the learning types relate to KI functions, the model provides a more concrete means of supporting learning than the currently popular distinction between single-loop and double-loop learning. While the previous subsections have illustrated how the model can be used to improve functional and interfunctional learning, the only learning type that has not yet been addressed is deutero learning, which will be addressed below.

In Subsection 5.4.7, it was concluded that the 65 incidents showed no examples of deutero learning but a multiple examples of a need for deutero learning. Deutero learning is initiated when people realize that their current way of working is problematic or not optimal, or when they realize that they do not improve fast enough. This realizing is necessary to start changing things. Deutero learning can be further facilitated by instruments that show actors where and how things can be improved. When we now think of the objectives of a systemic KI, we see that such a model is developed exactly for these purposes: creating awareness of KI and facilitating the improvement of KI. This suggests that by applying the model to KI in practice we have confirmed and further characterized the need for it; that is, the systemic KI model can initiate and facilitate deutero learning of KI. Using the model, actors can proactively and intentionally rather than reactively and unintentionally identify, explain and solve KI problems in their organizations.

5.5.8 Conclusion on the Model's Fit with the Problem

The preceding seven subsections have provided a number of examples of how the systemic model can be used to improve KI in practice. It was shown how the seven characteristics provide different perspectives on potential improvements. For example, in the example of Agrigen trying to expand its market to China, we have seen that this problem can be analyzed from the perspective of system barriers, but also from the perspective of interchanges. Following the principle of equifinality, we believe it is unimportant which of these perspectives would provide the 'right' solution. There are more solutions for each problem and the systemic KI model provides a means to find these alternative solutions. While the provision of KI solutions is potentially an important contribution of the model in practice, it is only so when these solutions are provided on time. Hence, there is one additional criterion which is important to assess the model's relevance: the timeliness of the model.

5.6 Assessment of the Timeliness of the Model

The final relevance criterion that De Leeuw mentions is the timeliness of the research. This criterion is particularly important in research projects where a model is developed for a particular actual situation in an organization. In these cases, there is a real problem that asks for a timely solution. In this study, there is no such particular actual situation. The model developed in this study is a general model that could be used in multiple future situations. Hence, it could be argued that, in this study, timeliness is less relevant than the other criteria.

However, we believe this is not the case. While we cannot evaluate whether the model was delivered on time, we can assess whether the model is likely to provide timely solutions in real cases. In this sense, timeliness refers to the timeliness of the model in KI problem solving. Section 5.5 has illustrated that the model can be used to identify and explain problems and to suggest solutions retrospectively. Additionally, below, we will assess whether the model is likely to be able to be used *before* the emergence of KI problems (i.e. to avoid them) and *during* the emergence of KI problems (i.e. to solve them). As we will not test in practice whether the model can indeed be used before and during the emergence of KI problems, this will be a hypothetical assessment.

We believe the model can be used to avoid KI problems when it becomes an incorporated part of a KI system. When the model is incorporated in the mental models or routines of the people and technologies that perform and control KI, we believe they will be able to improve their KI proactively, before problems occur. As such, the use of the model would be very similar to the use of quality models. Examples are the Dutch INK model (Institute Dutch Quality, http://www.ink.nl) and the ISO 9000 quality management standard (http://www.iso.org). Similarly to the systemic KI model, these models try to provide a systematic overview of organizations that is to be used for the alerting, diagnosis, improvement, and control of organizations (http://www.ink.nl). Also, similar to the systemic KI model is that, although these models contain normative elements, it is the user of the model who chooses the norms that will guide the improvements. Since these models are – assumingly successfully – used in practice for the improvement of organizations, we believe that the systemic KI model also will be able to play such role for the improvement of KI. Hence, we conclude that when used in practice, a systemic KI model will indeed be likely to be able to avoid the emergence of KI problems. We have to add to this, however, that the model in its current form will require a translation from its current scientific form to a more practice-oriented form. As this concerns future improvements of the model, we will come back to this in the final chapter.

We also believe that the model can be used during KI problem solving. While we argued that for the avoidance of KI problems the model should be incorporated in the KI system, we believe this is not necessary during KI problem solving. For this latter purpose, the model can be used as an instrument, or tool, that is used incidentally, rather than on a continuous basis. As the model is rather complex, we believe that the model is not very suitable as an instrument for solving short-term problems that require immediate solutions. For these problems, the use of the model will probably take too long. However, when problems do not require immediate solutions, we expect the model could be successfully used as an instrument for timely problem solving – again, when it is sufficiently translated to KI practice.

5.7 Discussion and Conclusion

This chapter started with the research question: *What is the soundness and relevance of the developed systemic KI model and how should it be improved?* It was subdivided into the following subquestions.

a. To what extent is the model sound and should its soundness be improved?
b. To what extent is the model relevant for KI problem solving and should its relevance be improved?

In order to answer these research questions, the chapter started with a concise assessment of the soundness of the model, which included an assessment of its consistency, precision, and correctness. Although not empirically tested, it was concluded that the model should be sufficiently sound for this stage of development by the systematic way in which it was built on KI literature (Chapter 2), empirical data (Chapter 3), and a model from social systems theory (Chapter 4). Rather than further improving its soundness, it was decided to assess and potentially improve the relevance of the model (i.e., its manageability, fit to the problem, and timeliness).

The manageability and fit with the problem were assessed by confronting the model with examples of KI in practice. These examples were gathered by conducting 17 critical incident interviews in high-tech SMEs. This yielded 65 critical incidents of KI in practice. As a result of this method, we were unable to develop an in-depth case in which the model could be assessed as a whole. Alternatively, we have chosen to assess the seven characteristics of the model separately. While this is a limitation of this study, we believe the chosen method of assessment yielded a wide set of results that also was suitable to assess the model for its manageability and fit with the problem. To assess and improve the manageability of the model it was tried to reduce its complexity by omitting parts that did not seem necessary to model the incidents. Additionally, by providing specific examples of KI the manageability of the model was made more concrete. Consequently, a subset of the 65 critical incidents was used to assess and improve the model's 'fit with the problem'. This was done by showing how the model could improve KI in the incidents. The timeliness of the model was assessed by arguing that the model could be used before and during the emergence of KI problems.

The result of the assessment and improvement of the model is a model that is not so much simpler, but that is better adjusted to the KI context than the model of Chapter 4. The suggested specific changes for the seven characteristics can be found in Section 5.4. Additionally, the potential usefulness of the adjusted model has been shown in many examples in Section 5.5. While these examples are not exhaustive, we believe they have sufficiently demonstrated the usefulness of the model for improving KI in practice.

While the model was not explicitly compared to existing models, it is obvious that the model is able to identify more problems and/or solutions than existing models can do; if only because it incorporates the currently most comprehensive model of Kim (1993) and extends it substantially. For example, since the model of Kim does not explicitly recognize the various elements of a KI system, it is not able to identify the corresponding problems and solutions highlighted in Section 5.5.1.

In the assessment of the manageability of the model, we have only considered its complexity and not the two other aspects of manageability: understandability and the form in which the model instantiates. Hence, we can only conclude here that with respect to these two other aspects, the current version of the model is probably not manageable. The final chapter will suggest directions for further research in order to also assess and improve these two aspects of manageability.

CHAPTER 6: CONCLUSIONS, LIMITATIONS, AND IMPLICATIONS

"Parsons can indeed be shown to have produced a number of major theoretical problems, but this is due, to a great extent, to the nature of his attempt. It is a merit of his work that he has sought to answer questions where others have not even seen the possibility of a question"

Savage (1981: 235)

"[...] the general public and its strategic decision-makers often err in making a definitive appraisal of social science on the basis of its ability to solve the urgent problems of society today. The misplaced masochism of the social scientist and the inadvertent sadism of the public both result from the failure to remember that social science, like all science, is continually developing [...]"

"The urgency or immensity of a practical social problem does not ensure its immediate solution. At any given moment, men of science are close to the solutions of some problems and remote from others. It must be remembered that necessity is only the mother of invention; socially accumulated knowledge is its father. Unless the two are brought together, necessity remains infertile."

Merton (1967: 49, 50)

6.1 Introduction

This study started with the question as to what systemic KI model could support the identification, explanation, and solving of KI problems that without such model would remain unidentified, unexplained, or unsolved. The objective of this study was to develop such model. In order to achieve this objective there were three research questions to answer:

1. What theoretical and empirical material for developing a systemic KI model can be derived from the current understanding of the KI process?
2. What systemic KI model can be derived from the framing of the gathered material into Parsons' social system theory?
3. What is the soundness and relevance of the developed systemic KI model and how should it be improved?

These questions have been answered throughout the past four chapters: Chapters 2 and 3 have answered the first research question, Chapter 4 the second, and Chapter 5 the third. In this last chapter we will 'tie the ends together'. Section 6.2 summarizes the most important steps and conclusions of this study. This is followed by a discussion of the limitations of this study in Section 6.3. Consequently we will elaborate on the contribution to the KI practice (Section 6.4) and conclude with the implications for research (Section 6.5).

6.2 Conclusions

In order to guide the development of a systemic KI model, we first had to demarcate what such a model would be like; that is, we had to define what a systemic KI model is in this study. To this end, Subsection 1.2.2 has discussed seven characteristics of a KI system divided into structural characteristics (a KI system consists of elements, boundaries, and an internal structure), behavioral characteristics (a KI system shows differentiated patterns of activities and interchanges between parts of the system), and control characteristics (a KI system is goal-directed and evolves in the course of time). While these seven characteristics characterize a *system*, additional demarcations were made in terms of the type of *model* that was to be developed. We concluded that the model should be a conceptual 'thinking model' that is based on the analogy of a system and that is used to select, interpret, and organize KI phenomena. From this starting point, we went through the answering of three research questions in order to develop such a model.

6.2.1 RQ1: Available Theoretical and Empirical Material

The first research question (*What theoretical and empirical material for developing a systemic KI model can be derived from the current understanding of the KI process?*) was split up into two research questions. RQ1a concerned a literature study in order to gather material for the development of the systemic model from the literature; RQ1b concerned an empirical study in which lacunas in the literature were filled.

Concerning the first part of the research question, a cross-disciplinary literature review was conducted covering a wide range of research fields, including organizational learning, knowledge management, information seeking, technology transfer, and research methodology. Within these fields we reviewed approximately 800 publications, in order to find whether and how these publications instantiated the seven system characteristics. The results of this review were presented in Chapter 2 in which we have invoked a little over 300 of the 800 publications. The review has demonstrated that on each of the seven characteristics there is substantial work done in previous research in terms of conceptualization and empirical research. However, it also appeared that none of the existing systemic models covers each of the seven characteristics. This implied that we could not select an existing model but had indeed to develop a systemic KI model. While this was to a large extent possible with the existing material, the literature review showed two gaps to be filled. The first gap concerned a lack of evidence for empirical patterning of KI activities. While some of the existing models seemed to draw on Parsons' version of social systems theory, empirical support was virtually lacking. Hence, additional empirical evidence was needed for the patterning of KI activities. The second gap concerned the problem that it would be impossible and undesirable to integrate all the reviewed material into one systemic model. The resulting model would be overly complex and impractical to use. This implied that we also needed to find a way for selecting parts of the collected material from the literature. It was decided that this selection should be made by applying an existing systemic framework. Considering that the patterning of activities is one of the most defining characteristics of a systemic model, it was decided that the choice for this framework should depend on the empirical patterning of KI activities.

With the identification of these two gaps, the first part of RQ1 has been answered. Consequently, we tried to fill these two gaps by means of an empirical study in the field of NPD in high-tech SMEs. Chapter 3 has discussed the two-stage research approach that was followed. It consisted of exploratory interviews with NPD managers of 33 high-tech SMEs and a survey amongst 317 high-tech SMEs. As a preparation for the survey, the 33 interviews provided three important results. Firstly, they provided us with a rich picture of how KI instantiated in the particular context of NPD in high-tech SMEs. Also, the interviews confirmed and further specified the need for a systemic KI model. Finally, the interviews helped us to learn the language of SME practitioners concerning KI in their specific context. Based on the outcomes and experiences of the interviews, we developed a questionnaire in cooperation with an expert group of practitioners and academics that participated in the KINX project (Knowledge Integration and Network eXpertise). While the largest part of this questionnaire was developed for the project's purposes, about one-fifth of this questionnaire could be used for the finding of empirical patterns of KI activities. After extensive pretesting with practitioners, this resulted in a questionnaire section consisting of 14 KI activities. An exploratory and confirmatory factor analysis of the results of the questionnaire have provided indications for a four function model that showed remarkable correspondence with Parsons' four functions of adaptation, goal attainment, integration, and pattern maintenance. Although the fit of the empirical results and Parsons' four function model was not perfect, we concluded that, combined with similar indications for this model in Chapter 2, Parsons' model should be used for the patterning of KI activities and as a framework for selecting relevant material from the literature. Hence, the two gaps that remained after the literature review were filled by the empirical study, implying that the first research question has been answered.

6.2.2 RQ2: Framing the Material into Parsons' Framework

After the answering of RQ1, we continued with the second research question, which read '*What systemic KI model can be derived from the framing of the gathered material into Parsons' social system theory*? The two subquestions were a) To what extent is Parsons' social system theory applicable to the KI context? and b) What systemic KI model can be derived from the framing of the gathered material into the applicable part of Parsons' social system theory? The answer to these questions was given in Chapter 4.

Because Parsons' theory is probably not well-known among some readers and has suffered a lot of – we believe partly undeserved – criticism, before answering RQ2, we have elaborated on Parsons' theory and some of its critiques. As argued there, Parsons' theory is not fully unproblematic. However, these elaborations have shown that it is not as grand, deductive, unempirical, deterministic, and conflict-empty as sometimes assumed and that not all of the critiques are relevant to this study.

In order to answer RQ2, we used again the seven system characteristics as they have been mentioned before. Chapter 4 has summarized Parsons' view on each of these seven characteristics. Consequently, the results of Chapters 2 and 3 were invoked to develop a systemic KI model based on Parsons' theory. The result of this endeavor was a preliminary version of a systemic KI model. Because of the preliminary nature of this model, we do not summarize the complete model here but refer to Sections 4.4 through 4.6 for a detailed presentation of the preliminary model on each of the seven characteristics. These sections also provide the detailed answer to research questions 2a and b. The final model, as it was changed after also answering the third research question will be summarized in Subsection 6.2.4.

6.2.3 RQ3: Evaluating and Improving the Systemic KI Model

After the development of the preliminary version of the systemic KI model in Chapter 4, the final stage of this study was an assessment of the model. The main purpose of this assessment was a further improvement of the model. The research question guiding this final stage was: '*What is the soundness and relevance of the developed systemic KI model and how should it be improved?*' This question was subdivided into the following to subquestions: a) To what extent is the model sound and how can its soundness be improved? and b) To what extent is the model relevant for KI problem solving and how can its relevance be improved?

The criteria of soundness and relevance already have been introduced in Chapter 1. Additionally, in order to answer the final research question, we had to decide how the model would be evaluated against these criteria. Concerning the soundness of the model (consistency, precision, and correctness), it was concluded after a concise discussion that the model should be sufficiently sound for this stage of development by the systematic way in which it was built on literature, empirical data, and a model from social systems theory. This conclusion provided the answer to research question 3a.

The first two relevance criteria (manageability and fit with the problem) were assessed by confronting the model with examples of KI in practice. These examples were gathered by conducting 17 critical incident interviews in high-tech SMEs. These interviews yielded 65 critical incidents of KI in practice. For both criteria, the seven characteristics of the preliminary model were assessed with these 65 incidents. To assess and improve the manageability of the model, it was tried to reduce its complexity by omitting parts that did not seem necessary to model the variety of the 65 incidents. Additionally, by providing specific examples of KI, the model became more concrete, which also improved its manageability. The two remaining aspects of manageability – understandability and practically usable form – were not assessed. We will return to these in Subsection 6.5.2. After the assessment of the manageability of the model, a subset of the 65 critical incidents was used to assess and improve the model's fit with the problem. This was done by showing how the model could improve KI in a number of detailed KI incidents.

Concerning the third relevance criterion, timeliness, it was argued that the model likely could be used before and during the emergence of KI problems. Hence, it was tentatively concluded that the model met this final criterion. As such, this analysis has provided an answer to the final research question.

6.2.4 The Outcome: a Systemic KI Model

With the answers to the three research questions we have arrived at the final outcome of this study: a systemic KI model that should support KI managers with the identification, explanation, and solving of KI problems that without such model would likely remain unidentified, unexplained, or unsolved. The result of the assessment of the model in Chapter 5 is a model that is better adjusted to the KI context than the preliminary model of Chapter 4. While specific details of the final model can be found in Section 5.4, we can summarize the model as follows.

Elements of a KI System

The elements of a KI system are the smallest building blocks of which it consists. In Chapter 4, we have suggested five types of such elements: actors, information technologies, non-information technologies, KI activities, and knowledge, of which the latter was further decomposed into knowledge residing in actors, in information technologies, in non-information technologies, and in activities. After the assessment of this first characteristic in Chapter 5, a small modification was made in terms of omitting actor's role as professionals. Figure 4.1 has graphically presented the elements of a KI system. This figure is repeated below in Figure 6.1.

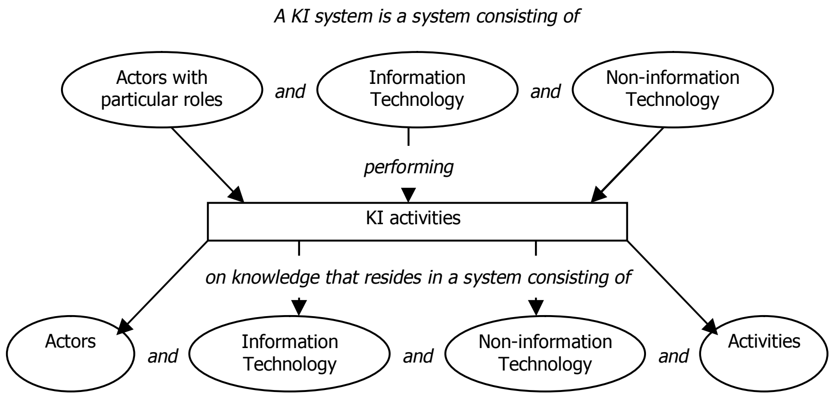


Figure 6.1 The elements of a KI system

Boundaries of a KI System

A KI system does not include all elements that exist. Rather, it is demarcated by some form of boundary that distinguishes it from its environment. While the preliminary model in Chapter 4 has included the notion of permeable and changing system boundaries, the assessment in Chapter 5 has indicated that this notion is not congruent with KI in the NPD practice of high-tech SMEs. Hence, it was argued that concerning this second characteristic, a systemic KI model should recognize that a KI system can be gradually distinguished from its environment by means of the notions of interaction density and system barriers. Interaction is denser near the kernel of a system and gets gradually less dense at its peripheries until the system dissolves in the environment. For each dyad of system elements, there can exist various and different barriers that make interaction more difficult. In order to facilitate interaction, barriers can be avoided by interacting with other actors or by choosing a different type of interaction. This way of distinguishing a KI system from its environment was depicted in Figure 5.1 and is adapted below (Figure 6.2, in which line thickness represents interaction density and 'x' represents a potential barrier).

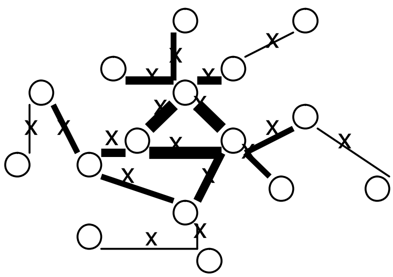


Figure 6.2 Interaction and barriers to distinguish a KI system from its environment

Internal Structure of a KI System

A KI system is not simply an aggregation of elements with relations. Rather, it is a hierarchical system consisting of levels and subsystems. In Chapter 4 it was suggested that, concerning this third characteristic, a systemic KI model should recognize that a KI system consists of four functional subsystems (adaptation, goal attainment, integration, and pattern maintenance) that are, like the KI system itself, controlled by controlling organs (COs). Also, though not instantiated as subsystems, a KI system fulfills three knowledge functions (identification, acquisition, and utilization of knowledge) at both the level of the KI system and the level of subsystems. After the assessment in Chapter 5 it was concluded that no further modifications were needed concerning this characteristic. Figure 4.3 represented it as follows (see Figure 6.3).

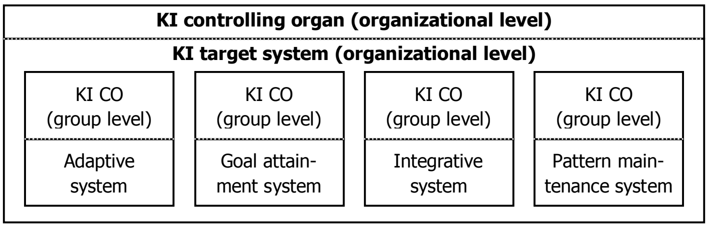


Figure 6.3 The internal structure of a KI system

Differentiated and Patterned KI Activities

While the previous three characteristics of a systemic KI model describe what a KI system is, a KI system also does something. In other words, it shows particular behavior in the form of patterns of KI activities. As argued in Chapters 3, 4 and 5, KI activities are patterned around the four system functions. This means that KI activities are supposed to contribute more to one function than to another function without being exclusively attributed to that function. This also means that in order to fulfill a particular function, a pattern of KI activities is involved. Additionally, considering the equifinality of a system, alternative (patterns of) KI activities can lead to the same outcome. The four patterns were described in Chapter 4 as follows:

- *Adaptive KI:* the ability of the system to be receptive to changes in or introduced by external sources of knowledge.
- *Goal attainment KI:* the ability of the system to set and achieve goals by identifying, acquiring, and utilizing knowledge from external sources.
- *Integrative KI:* the ability of the system to develop into a coherent whole, by dissemination and integration of external knowledge in the system.
- *Pattern maintenance KI:* the ability of the system to create and maintain a stable and close relationship between elements of the system.

Additionally, in the model, KI activities should be categorized according to knowledge functions. Although knowledge functions are not associated with patterns of KI activities but with categories, these functions remain an important part of the model.

Interchange in a KI System

A second behavioral characteristic of a KI system is that interchanges take place between the system and its environment and within the system. As argued in Chapter 4, interchanges consist of an interchange of knowledge for other knowledge, or for generalized media. Also, interchanges can be direct or indirect, the latter meaning that the interchange between two actors occurs via at least one other actor that, in effect, operates as an intermediary. Interchanges were conceptualized in Chapter 4 as interchange systems that, like the functional subsystems, have their own controlling organ. Interchange was represented in Figure 4.5, and remained unmodified after the assessment in Chapter 5. Figure 4.5 is adapted below (see Figure 6.4, in which each pair of arrows represents an interchange system that is controlled by a controlling organ).

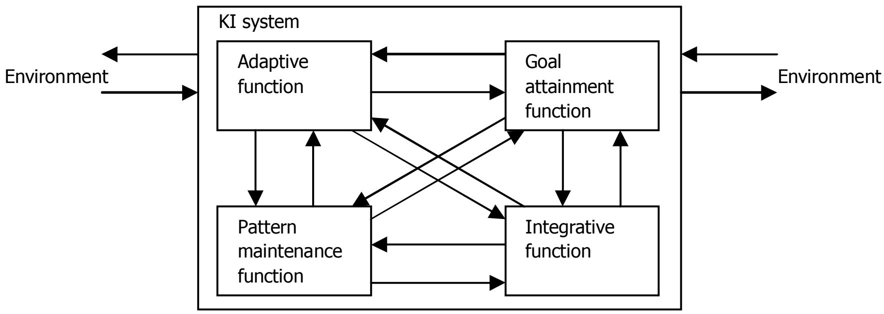


Figure 6.4 Interchanges in a KI system

Goal-Directedness of a KI System

KI activities and interchanges do not take place without reason. Rather, they are directed by goals of the actors that perform them. Goal-directedness, then, is a sixth characteristic that should be covered by the systemic KI model. As such, it is the first control characteristic. The systemic KI model as presented in Chapter 4 recognizes that the controlling organs of the KI system, of its environment, of its subsystems, and of individual actors each may have their own goals. Goals can have a situational, cognitive, and affective origin. Moreover, goals are formulated in interaction between actors and not by individual actors or (sub)systems. Goals of different actors or (sub)systems may be conflicting. Also, goals have intended and unintended consequences that mutually affect the achievement of other goals. This conceptualization of goal-directedness of a KI system remained unmodified after the assessment in Chapter 5. Goal-directedness was depicted in Figure 4.6, which is repeated below (See Figure 6.5, in which at each of the nodes, a new circle could be added).

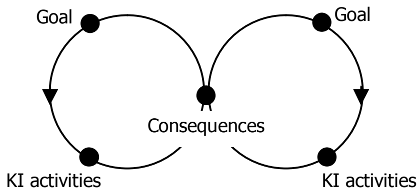


Figure 6.5 Goal-directedness in of a KI system

KI System Evolution

While the preceding six characteristics have presented a KI system as a dynamic, but stable system, KI systems also evolve in the course of time. Therefore, a final characteristic that should be recognized by a systemic KI model is the evolution of a KI system. This characteristic forms the second control characteristic. In order to conceptualize it, Chapter 4 distinguished between functional learning, interfunctional learning, and deutero learning and between a cognitive and a behavioral aspect of learning. After the assessment in Chapter 5 no modifications were made. This final characteristic was depicted in Figure 4.7, which is included below. In Figure 6.6, functional learning is modeled by the loops between a functional subsystem and its controlling organ (the ellipses); inter-functional learning by arrows from one functional subsystem connecting to arrows to the controlling organ of another functional subsystem; and deutero learning by the dotted arrows.

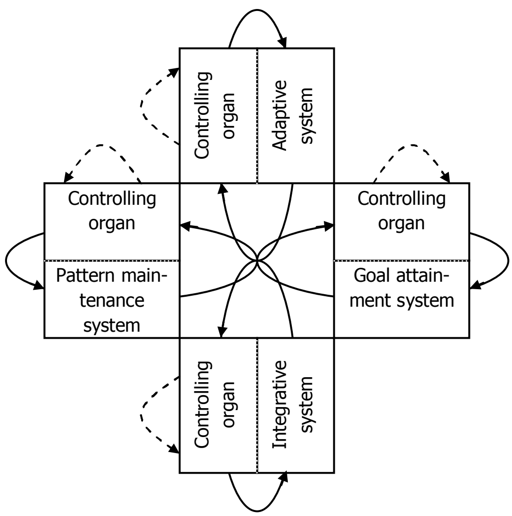


Figure 6.6 Learning in a KI system

In sum

Together, these seven characteristics comprise a systemic KI model. As such they comprise the answer to our main question, which read: '*What systemic KI model can support the identification, explanation, and solving of KI problems that without such model would remain unidentified, explained, or solved?* The usefulness of the model summarized above has been illustrated in many examples in Section 5.5. While these examples are not exhaustive, we believe they have sufficiently demonstrated the potential usefulness of the model for improving KI in practice. While the model has not been explicitly compared to existing models, it is obvious that the model is able to identify more problems and/or solutions than existing models can do; if only because it incorporates the currently most comprehensive model of Kim (1993) and extends it.

We can now ask the question whether the objective was achieved. We believe so. The outcome of this study is indeed a systemic KI model. Also, it seems to show the complexity and coherence of KI in practice and it seems to be able to support the identification, explanation, and solving of KI problems that are less likely to be identified, explained, and solved without the model. Hence, we conclude that the objective has been achieved by developing a systemic KI model that is sound and relevant as we might expect from a model at this stage of development. Does this mean the model cannot be improved? Undoubtedly not. While, in general, any research outcome can be improved, this applies particularly to research outcomes of a theory (or model) development study like this. Developing a model creates uncertainties that only further research can try to reduce. Also, as any other study, this study has not been without its limitations.

6.3 Research Limitations

A number of choices have been made in order to conduct this study. Whereas without them, any study would be impossible, these choices impose limitations on this study if only because they exclude unexplored opportunities. While we could discuss limitations of each minor choice that was made within this study, we limit ourselves to those choices that have had a major impact on the study. These concern the choice of 1) developing a systemic KI model, 2) the research context, 3) the literature and data collection, and 4) the analysis.

6.3.1 Limitations of a Systemic Model

A first type of limitation of this study originates in its objective to develop a systemic KI model. This objective implies that the outcome of this study suffers from (at least some of) the limitations of systems theory. We have attempted to address a number of these limitations in this study, including a lacking focus on network structures, a lack of attention to conflicts, and the abstract nature of systems theory. However, there are other limitations inherited from systems theory that were not addressed.

Firstly, systems theory is based on a functional perspective of actors and systems. This means that it is assumed that these are trying to reach goals effectively. Thus, it was assumed that actors perform KI activities if these are considered an effective means to reach their desired ends. Other reasons for performing these activities, for example, because these are fun to do or most easy to do, are left out of consideration. There is, however, evidence that also these play a role in KI. For example, among others, Case (2002: 140) and Gerstberger & Allen

(1968) demonstrate how the 'the principle of least effort', accessibility, and playfulness affect the selection of sources of information. We have no reason to assume that this is not the case for the selection of KI activities. While the distinction of situational, cognitive, and affective goals forms some protection against a too functionally oriented model, we believe the current model does not take these kinds of drivers of behavior fully into account.

Secondly, since the systemic KI model concerns only one aspect of organizations, its use not necessarily contributes to the performance of an organization as a whole. While we have modeled KI as a rather separate aspect of organizations, in practice, it is intertwined with other aspects, including product development, finance, production, and human resource management. Since this study has only focused on KI, we currently do not know whether an improvement of KI performance is associated with an improvement of the performance of the organization as a whole.

Thirdly, as a systemic model, the KI model is not very well capable to deal with revolutionary change and the perishing of KI systems. In the collected literature and empirical material we found no occurrences of revolutionary change in KI, or of the perishing of KI systems. However, we cannot exclude the possibility that these notions do play an important role in KI.

Fourthly, since a hallmark of good theory is parsimony, the complexity of the resulting model could be seen as a weakness of this study. While the model is already less complex than the model it was based on (i.e., Parsons' social system theory), the systemic KI model remains relatively complex compared to other models. As demonstrated in Chapter 2, there are already many studies on KI that aim at simplicity; that is, they provide a general or accurate model of part of the KI process. The contribution of this study is that it puts these existing models into perspective in a model that is both general and accurate. It would have lowered the quality of the model if it also had aimed at simplicity (Thorngate, 1976; Weick, 1969). Hence, we believe that, considering its purpose, the model is parsimonious.

Finally, the way we have represented the systemic KI model by decomposing it into seven characteristics that are grouped in three classes might lead the reader to feel that KI is presented as too mechanistic or too structured and that too little attention is given to the more organic and evolving character of KI in practice. While this might indeed be a result of the way of presenting the systemic KI model, we want to stress here that the model has to be seen as a whole and that its core consists of evolving patterns of KI activities performed by actors using technology.

6.3.2 Limitations of the Research Context

A second type of limitation originates from our decision to focus on the research context of new product development in high-tech SMEs. Since no other contexts were scrutinized, this currently limits the applicability of the model to this particular context. NPD is a knowledge-intensive business function where, as mentioned in Chapter 1, existing knowledge is integrated into a new product. Moreover, in high-tech SMEs, NPD is one of the core functions of the company, implying that other business functions are supporting NPD. Together, this suggests an almost perfect fit between KI and NPD: both concern the integration of knowledge and both can be considered to form the core of a high-tech SME.

Because of this almost perfect fit, the applicability of the systemic KI model cannot be extended to other research contexts only on the basis of this study.

When we consider another knowledge-intensive business function, for example, finance of the company, we believe that the seven characteristics of KI also instantiate in this context. We suspect, however, that they will instantiate differently. For example, in terms of system elements different information technologies will be used and the role of non-information technologies will probably be less dominant than in KI for NPD. Also, we expect that the role of external and new knowledge is less important than in KI for NPD. These examples suggest that, with modifications, the model also will be applicable to other knowledge-intensive business functions.

Considering the type of company, the high-tech nature of the companies makes that they are knowledge-intensive businesses. We suspect that for knowledge-extensive industries the model might still be applicable, but is not relevant. The high-tech *manufacturing* nature of the companies triggers the question as to what extent the systemic model is applicable to knowledge-intensive industries in which nothing is manufactured. Examples are software, consulting, and service-oriented organizations. We expect that while, for example, in manufacturing firms particularly non-information technologies are important carriers of knowledge, in software companies information technologies will probably be more important, and in consultancy firms and service-oriented organizations actors will be more important. Hence, we believe that in these industries the model will be applicable, but needs a different emphasis.

With respect to the size of the company, we believe that particularly for what was said about the system's boundaries and structure, the applicability is unsure for larger firms, or at least for bureaucracies. The model depicts KI systems as networks of – directly and indirectly – interacting actors where organizational boundaries are less important. This conceptualization of system boundaries and structures does not seem to fit very well with the way large firms traditionally are organized. However, cooperations between larger firms seem to become more and more common practice. Recent examples in NPD are the co-development of the Senseo coffee machine by Philips and Douwe Egberts, and the co-development of the Beertender by Heineken and Krups. Although we suspect that the original conceptualization of system boundaries still fits better traditional large organizations, we believe that the systemic KI model as developed in this study also will be applicable to large firms that cooperate with other firms.

Finally, in this study we have chosen to limit the systemic KI model to the level of groups and organizations. This means that its applicability to higher levels of aggregation – the institutional and the societal level – is not investigated. It is argued in systems theory that systems are recursive and thus that system characteristics applicable to one level also should be applicable to other levels. While, in general, this could be the case, we believe further research is needed before we can judge whether the model also would be applicable to higher levels of aggregation.

6.3.3 Limitations of the Literature and Data Collection

In addition to the limitations imposed by the objective and demarcation of this study, also the gathering of research material has imposed its limitations. These limitations concern both the use of literature and the use of empirical material.

Although we have tried to conduct a thorough cross-disciplinary literature review, we inevitably have missed applicable literature. The question is whether this is problematic for this study. The first part of our answer is that we have found no other study that has covered a comparable number of disciplines. Hence, we believe that this study is the most interdisciplinary study of its kind, suggesting that it is not problematic that we might have missed additional applicable literature. The second part of our answer is that missing certain literature is only problematic as far as this literature would bring new results to the already reviewed literature. As concluded in Chapter 2, there are many similarities between the various reviewed disciplines. Although the focus of the various disciplines is different, similar characteristics of KI appeared across all of them. Hence, although we might have missed relevant literature, we believe the similarities between the various disciplines suggest that this is not problematic for this study.

Also concerning the collection of empirical data for the exploratory study and the evaluation study this study has faced limitations. With respect to the exploratory study of Chapter 3, a first limitation relates to the development of the questionnaire. Since we found no existing instruments that measured KI activities, we had to develop a new questionnaire. Moreover, we had to limit the length of the questionnaire because of the time that respondents were willing to spend on it. Although we have tried to address this limitation to the best possible extent with our pretest procedures, the reliability and validity tests are not convincing yet. The support of the four-functions model is not conclusive in terms of factor loadings, reliability, convergent validity, and discriminant validity. While this is not surprising since we did not plan in advance to test the four-functions model, it is a limitation of this study. However, considering that the 4SF model was reproduced for both customer/market and technological knowledge, we believe this limitation has had no substantial impacts on the outcomes of this study.

Also, the data collection of this exploratory study was not without limitations, in particular because the selection of a sample from four different databases formed a potential source of bias. We have investigated the impact of this limitation by comparing the results of the four countries. Whereas the mean values for each of the items of the questionnaire differ significantly between the countries, the four-functions model remains rather stable when the data from single countries are excluded from analysis. Thus, we have confidence that this limitation has had no substantial impact on this study. Also the self-selection of respondents within the companies might have introduced bias, for example, by only reaching the 'champions' of the company. Since we did not consider the respondent to be a representative of the company, but rather to be a knowledgeable person in the company we believe this is not problematic. We assumed that the companies would know better who was knowledgeable than we would. Hence, we believe that self-selection was the best alternative.

An important source of these limitations is that the exploratory study was conducted as part of another study – the European project 'Knowledge Integration and Network eXpertise' (KINX). This made that the exploratory study had to be performed in a very early stage of this study (i.e. before most of the literature review was conducted). Also, it made that only one fifth of the questionnaire was available for the purpose of this study. Despite of these limitations, we believe that it was beneficial to take part in the KINX questionnaire rather than to conduct a separate questionnaire ourselves. Firstly, the KINX project provided the opportunity to conduct this study in four countries, which would have been infeasible without the project. Secondly, the KINX project provided an expert group of practitioners and academics in the field of KI, which would have been hard to create without the project. Thirdly, it is very efficient when two studies benefit from the same questionnaire. Finally, the KINX project has provided a budget to conduct this study; without it, the study would most probably not have been conducted at all. Thus, we are convinced that the opportunities provided by the KINX project by far outweigh the limitations it has imposed.

In the evaluation study, only a relatively small number of respondents (17) were interviewed, which limits the generalizability to other groups of respondents. However, since the aim was to develop a model, it is not the generalizability to other groups that matters most, but the generalizability to that model (Lee & Baskerville, 2003). This implies that the examples of the respondents should be generalizable to the resulting systemic KI model. Generalizability was improved by the choice of the domain (NPD, which is one of the most challenging domains for KI and offers rich picking for examples), by the sampling strategy (minimizing and maximizing differences), by taking the 65 incidents rather than the 17 respondents as units of analysis, and by emphasizing the diversity of the examples.

Another limitation stems from the research method that was followed. Although the critical incident technique (CIT) is assumed to provide reliable and valid descriptions of events, it remains a retrospective method that possibly will give biased views. A central risk when reporting about KI retrospectively is that respondents will see the process as more structured than during the process itself. Consequently, their explanations of decisions will be more rational than they really were at the moment they were taken. However, by focusing on descriptions, the CIT tries to address this main weakness – and it does so successfully. Moreover, there are currently no better alternatives available since direct observation is infeasible.

Finally, concerning the usefulness of the model, it could be argued that we should have used the model as an intervention tool in practice or that we should have assessed the model as a whole in an in-depth case study. However, in order to assess the usefulness of the model, we had to make a compromise between a the variety of the examples (for the assessment of the manageability) and their depth (for the assessment of the fit with the problem). The CIT seemed the most suitable method to gather such data. As we have chosen for the CIT it was not possible to also conduct other research methods. While this is a limitation of this study, we believe it is not to be expected that a complex model as the systemic KI model can be fully developed and tested within one PhD project. While testing the model in practice will be a necessary step for future research, it was simply impossible to also include it within this study.

6.3.4 Limitations of the Analysis

While the limitations of the collected material automatically affect the analysis, the latter imposes additional limitations. An important limitation in the analysis is the researcher. In general, humans are bad observers: they make up information; they overgeneralize; they see what supports their claim and don't see what does not support their claim; and they are good at recognizing patterns but not good at recognizing non-patterns (Case, 2000: 161; Keohane, Verba, 1994: 21). The fact that most of the analyses in this study were conducted by a single researcher increases the likelihood of researcher bias. As a measure against researcher bias we have used an existing framework from systems theory for our analysis. Also, we have triangulated literature and qualitative and quantitative empirical material. Additionally, while most of the analysis was conducted by one researcher, the study was not conducted in isolation. The results of the analyses have been elaborately shared and discussed with multiple participants of the KINX project, supervisors, peers, and reviewers, which also reduces the likelihood of researcher bias. Finally, we have followed explicit procedures for the analysis (e.g. factor analysis and the constant comparison method). Perhaps we could have further limited researcher bias by conducting the analysis of the *evaluation* study together with multiple researchers (because of its standardized procedures, this does not seem to have a substantial effect on the statistical analyses of the *exploratory* study). However, in practice this is hardly a feasible way of working. 768 pages of interview text make that a researcher has to spend many days fulltime in the analysis. Research also using the constant comparison method (e.g. grounded theory) has shown that it is very uncommon that multiple researchers spend this amount of time on analysis (Länsisalmi, Peiró, & Kivimäki, 2004: 249). Considering this and the aforementioned measures that were taken to reduce researcher bias, we believe we have done what was feasible in order to limit researcher bias.

The study's focus on model development makes that the results are more tentative than in a theory testing study. The model reflects a number of ideas that have not been extensively tested. This implies that we cannot conclude at this stage of the development that the soundness and relevance of the model is maximized. Since this is natural to theory development studies, we do not believe this limitation is problematic.

6.3.5 Conclusion on the Limitations

The previous four subsections have highlighted a number of limitations of this study. It was argued that at many points in the research choices have been made. Although we always have explained these choices, they remain – at least partially – subjective. The result of this study is a model of KI that is more complex than any other existing model of KI. Also, this study has perhaps generated more questions than it has answered. Does this study, then, still provides a contribution to research and practice? We believe so. The model has not made KI more complex than it was. Rather it has demonstrated its complexity and coherence in a more elaborate way than existing models have done so far. The following two sections will discuss how this forms a contribution to practice and what implications it has for research.

6.4 Contribution to Practice

The objective of this study was to develop a systemic KI model that supports the identification, explanation, and solution of KI problems that without the model would have remained unidentified, unexplained, or unsolved. By confronting the model with examples of KI in practice, Section 5.5 has demonstrated that the model, in principle, can meet this objective. Additionally, to increase the likelihood that this contribution to practice will indeed be made, this section will suggest how this contribution can be made. As a 'thinking model', the systemic KI model is an instrument rather than a theory. De Leeuw (1999) argues that a good instrument informs its user about 1) what can be done with the instrument, 2) in which cases it can be used, 3) how it should be used, and 4) which competences are required to use it. The following subsections will each address one of these requirements.

6.4.1 What Can Be Done with the Model?

Concerning the first requirement, Chapter 5 has already provided many examples of what can be done with the systemic KI model: it can help to solve KI problems that without the model would probably have remained unsolved. Also, it was argued that in this role, the model supports deutero learning of KI. Considering that this first requirement was explained rather extensively in Subsection 1.3.1 and considering that Chapter 5 has put much emphasis on this first requirement, we will only invoke a few examples in which the model was used for the three KI problem solving tasks that were mentioned.

Firstly, for the task of KI problem identification, the model can be used to provide practitioners with more things to look at than other existing models do. In other words, it can make practitioners more sensitive to the perception of KI problems. This can lead to earlier problem detection or the detection of more problems. Examples of this role were given throughout Section 5.5 by demonstrating how the model could have identified problems in the critical incidents.

Secondly, for the task of KI problem analysis, the systemic KI model can be used as an explanatory instrument. The model itself does not provide the explanation (or cause) of the problem (otherwise it would not have been a 'thinking model' but an explanatory model). Rather, it facilitates practitioners in finding explanations by showing interlinkages between parts of the model. One example of this role was given in Subsection 5.5.3 where it was discussed that, at Clensco, the problem of the empty project database was decomposed into a goal attainment function and an integrative function. This decomposition helped to explain the problem.

Finally, for the task of solving a KI problem, the model can be used as a prescriptive instrument that helps to generate alternatives (or at least one), to facilitate the choice of alternatives and to design and implement these alternatives. An example of the prescriptive role of the model was given in Subsection 5.5.1 where the director of Eltrode could have chosen to play a role as a marketing specialist as an alternative to his role as company representative.

6.4.2 In which Cases Can the Model Be Used?

Subsection 6.3.2 has discussed the limitations of this study imposed by the focus on the particular research context of NPD in high-tech SMEs. There it was argued that the model might be applicable to other contexts, but that it might need some adjustments for that. We believe this also holds for the cases in which the model can be used in practice: in the current form of the model, these cases are limited to this particular context. Within this context, we can further specify the cases by looking at the type of problems that can occur. Three important dimensions to characterize problems are the complexity of the problem (simple vs. complex), the uniqueness of the problem (one time only vs. recurrent) and the impact of the problem (minor vs. major). We believe the use of the model is limited to those problems that have a major impact. For KI problems with little impact, we believe it is not worthwhile using the model. For these problems, the expected benefits of solving them do probably not outweigh the costs and efforts of using the model. Concerning the other two dimensions, Table 6.1 suggests for which types of KI problems it seems likely that the model can be used.

Table 6.1 Types of problems for which the model can be used.

	Simple	Complex
Unique	No	Maybe
Recurrent	Maybe	Yes

As Table 6.1 demonstrates, we believe the systemic KI model is most useful for the description, explanation, and solving of complex, recurring, important problems. As they are complex, it seems likely that also a complex model as the systemic KI model is needed for solving these problems. Additionally, as these problems are recurring, finding a solution for them might bring frequent benefits. Finally, as they are important problems, the benefits of solving them are likely to be high.

For simple problems the model seems simply too complicated to use it. For this type of problems practitioners most probably will not need such a complex model. Rather, they will simply solve the problem. An exception is simple problems that are recurring and do have much impact. When they are recurring, practitioners probably have not found a solution yet, despite of the relatively large impact. Although the model might be overly complex for these problems, it will probably at least lead to a solution.

For unique KI problems we believe that, in general, also the model is perhaps too complex to use. It might not be worth the effort when a problem occurs only once. However, when the problem is very complicated and important it might still be useful to use the model.

6.4.3 How Should the Model Be Used?

The third requirement that De Leeuw mentioned was that it should be clear how the model should be used. While it is not possible on the basis of the outcomes of the current study to provide a complete method of how the model *should* be used, we can give three types of indications about how it *can* be used in practice. The first type of indications refers to the KI problem solving process it can be used in; the second to the discussions on the timeliness criterion in Section 5.6; and the third to the model itself.

A first type of indication stems from the aforementioned problem solving process. It was mentioned that the model can be used for the identification, analysis, and solution of KI problems. Since these concern three different roles of the model, this suggests that they ask for different ways of using the model. As for problem identification, we believe the most natural way to use the model is as a monitoring instrument, for example as a quarterly checklist in which KI is systemically checked on each of the seven characteristics. By regularly examining the organization, practitioners might be able to detect KI problems in an early stage. Problem analysis and solution might either follow after this identification stage or after a clear problem has occurred. As such, the model is to be applied to further define and structure a specific problem, to diagnose its causes, and to develop a solution for the specific problem, while taking into account the effect of the solution on the system and not only on the specific problem.

Other indications can be found in the discussions on the timeliness of the systemic KI model. In Section 5.6 it was argued that the model could be used before and during the origination of KI problems. As the elaborations there have shown, these two moments concern different ways of using the model as well. Firstly, the model can be used, like a number of quality management models, as a model that should be incorporated in the mental models and routines of the KI system. As such, it should improve the general performance of KI and prevent KI problems. Secondly, the model can be used as an instrument to assess KI on an more ad hoc, or periodical basis.

While these indications of how the model can be used originate from the problem solving process, additional indications stem from the way the model was constructed. Throughout this thesis, the model was consistently described by the seven characteristics of the model, starting with the structural characteristic of KI system elements and ending with the control characteristic of KI system evolution. At this stage of the development, we cannot claim that this particular order is the best order in which to apply the parts of the systemic model. However, we believe that it is a rather logical order since there is an increased and cumulative complexity for the subsequent characteristics. Also, in our experience it was a fruitful order in doing the analyses of Chapters 2, 4, and 5. Hence, it is tentatively suggested to apply the model in the same order as done in this study.

Before the model can be used in the suggested ways, its soundness and relevance require further improvement. Section 6.5 will make a number of suggestions for such improvements.

6.4.4 What Competences are Required to Use the Model?

The final requirement concerns the required competences of the user of the model. It does not require explanation that in order to use the model, the user should know what the model can be used for, in which cases it can be used, and how it should be used. However, additionally, the user needs particular competences in order to be able to use the model effectively. As we have argued before, the intended user of the systemic KI model is the controlling organ (CO) of the KI system. When we follow De Leeuw, in order to be able to control a KI system, such a CO should answer the following five criteria:

1. It should have a goal. Considering that we have elaborated on goals extensively, we believe this requires no further explanation.

2. It should have a model of the KI system. With the term model, De Leeuw refers here to causal models of the causal mechanisms in a system. While we have not developed such a model, we have argued that the model developed in this study can be used to find causal mechanisms.
3. It should know the environment and current situation of the system. Put simply, this criterion implies that the CO should know how KI is performed in practice in the KI system at hand.
4. It should have sufficient measures for control. When we translate this criteria to the terminology used in this study, it implies that the CO should have sufficient generalized media to influence the KI system.
5. It should have sufficient information processing capacity. The CO should be able to achieve its goals (1) by using the model (2) to turn his knowledge about the KI system (3) into an effective control measure (4).

When we consider these criteria, we see that the persons that are to use the model need a number of competences: they need to be able to formulate goals for the KI system, they need to be able to use the systemic KI model, they need to know how KI is performed in their KI system, they need to be in the position to influence the KI system, and they need to have sufficient analytical skills. Considering these required competences, we believe it to be fruitful when the model is initially applied by a trained consultant in close cooperation with the director of an organization, project leader, or team leader. After a period of use we expect that the need for a consultant diminishes. However, initially, the consultant is needed for his or her knowledge about the systemic KI model; while the director, project leader, or team leader is needed for his knowledge about the KI system, for his goals and for his position to exert control measures. An alternative would be that the director, project leader, or team leader, would apply the model without the help of a consultant. This might be feasible but we believe it requires extensive training in learning and using the model. Another alternative would be appointing a person in the organization specifically for applying the model. Perhaps this would be possible in organizations of 200 persons or more, but we believe that most SMEs are not sufficiently large and differentiated for having such a specific position.

6.5 Implications for Research

In addition to the implications for practice, this study also has implications for research, which will be discussed in this final section. After an assessment of the contribution of this study to research in Subsection 6.5.1, we present directions for further research. These concern a further improvement of the soundness and relevance of the model (Subsection 6.5.2), and suggestions for new research directions that should be explored using the model (Subsection 6.5.3).

6.5.1 Contribution to Research

As presented in Subsection 1.3.2, the targeted scientific contribution of this study was an improvement of the cumulativity of KI research. We believe this study has made this contribution in two related ways.

Firstly, this study forms a accumulation of past research by and in itself. By using the seven characteristics for the literature review in Chapter 2, this study has structured existing research on KI. As such, Chapter 2 forms a accumulation of research on KI. Also, since the invoked literature originated in different research disciplines, this accumulation of research is less bounded to a particular discipline than previous studies we are aware of.

Secondly, the outcome of this study – the systemic KI model – provides a composition and organization of the concept of KI. As such, the model can improve cumulativity of research when a substantial number of researchers accept it as a conceptualization of KI. We suggest the model should be used as an integrative reference model to place existing and future KI research into perspective. This does not mean that all KI research should be of an integrative nature. On the contrary, careful studies on parts and aspects of KI are necessary in order to develop in-depth knowledge about them. However, when carrying out such studies, researchers should be clear on which part or aspect KI they concentrate, and what the consequences are of their chosen focus. As the model abstracts from specific research disciplines, it also can support the accumulation and performance of interdisciplinary and multidisciplinary research.

While these two ways are important for the improvement of the cumulativity of KI research, they are only first steps. Further cumulativity of KI research can be attained when other scholars will use the model in their research as a shared view on the KI concept. When this is done, we believe that the outcomes of future research also will be more helpful for KI problem solving in practice.

In addition to providing an organized composition of KI that can foster the cumulativity of research, this study also provides a reconceptualization of KI. Although it was Grant (1996) who explicitly argued that "[...] the primary role of firms, and the essence of organizational capability, is the integration of knowledge" (1996: 375), we feel that the current conceptualization of KI provides a more realistic view of what it means to consider KI as the primary role of firms and as the essence of organizational capability, than Grant's own conceptualization. We have extended and enriched Grant's work in at least three ways: with respect to knowledge, with respect to its integration, and with respect to the evolution of KI.

Concerning 'knowledge', this study's conceptualization of KI demonstrates how knowledge residing in system elements (actors, technology, and activities) and in combinations of elements is to be integrated with the system of knowledge in the KI system. Another aspect that is highlighted in this study concerns that the four functions produce different types of knowledge that need to be integrated as well. Hence, without touching the specific content of the knowledge, this study has explicated the types of knowledge and knowledge carriers that are to be integrated in a KI system. While not completely new, we believe this systematic classification of knowledge reduces some of the ambiguities around the concept of knowledge. Also, it can help to further understand the nature of KI and KI problem solving.

Concerning 'integration', by categorizing Grant's mechanisms of direction and routinization as knowledge utilization activities, this study has argued that there is much more to KI than the mechanisms. For example, it involves KI activities aimed at adaptation (e.g. browsing and scanning), goal attainment (e.g., focused search and application), integration (e.g. diffusion and coordination), and pattern maintenance (e.g., cooperation and routinization).

Concerning 'evolution', this study has provided a conceptualization of learning in KI that is new both with respect to Grants' conceptualization of KI and with respect to the current conceptualization of organizational learning. Rather than focusing on single-loop and double-loop learning, this study has suggested functional and interfunctional learning as two new concepts of learning. As these concepts differentiate learning at the system level, they might form a means to bridge the gap between individual learning and organizational learning and such lead to a better understanding of KI and its dynamics.

With these extensions and enrichments of Grant's work, this study has potentially provided a conceptualization of KI as the primary role of firms. More generally, this study has started to address Spender's call to make knowledge the basis of a dynamic theory of the firm (Spender, 1996a). Spender argues for an activity systems approach that can "[...] probe for the knowledge processes that underpin the firm's boundary movement and evolutionary trajectory, and for their place in them" (Spender, 1996a: 56). By having conceptualized the structural, behavioral, and control characteristics of a KI system, this study can form a next step towards making knowledge the basis of a dynamic theory of the firm.

6.5.2 Improving the Soundness and Relevance of the Model

In this study we have tried to develop a sound and relevant systemic KI model that can be used for KI problem solving. In order to improve the ability of the model to support KI problem solving, both its soundness and relevance require further improvement.

The first direction for further research improving the soundness of the model is further empirical research on the patterning of KI activities into system functions (SFs). Such research is needed because it can explain which KI activities contribute to which functions. When, in practice, a particular function is not performed well, information on the patterns of KI activities can help to find an explanation of why this is the case and what can be done about it. It seems surprising, then, that there is hardly any empirical research on the patterning of KI activities (see Chapter 2). As Chapter 3 has illustrated, such research is not impossible, nor is it inherently very different from other types of empirical research. Content-wise, this study can serve as a starting point for research on patterns of KI activities. It has provided a first tentative patterning of KI activities, a list of numerous other KI activities, and definitions of each of the four functions. Method-wise, this study has suggested exploratory and confirmatory factor analysis as possible methods to look for empirical patterns of KI activities. With the results of this study, it is now possible to follow a more deductive approach which starts from the definitions of the four functions, proposes patterns of KI activities, operationalizes them into a survey instrument, and test them in a number of domains. Additionally, qualitative methods aiming at in-depth descriptions of KI in a few organizations should be used to better understand the reasons why KI activities are patterned.

While this first direction for research suggests to find corroboration of the model, we also suggest to try to refute the model by a comparison of Parsons' theory with other system theories. Since both the literature review and the empirical study pointed in the direction of

Parsons' work, we have not further investigated alternatives within this study. However, in order to test and improve the soundness of the model we should investigate what we can learn from other systemic models and perhaps whether other systemic models can form a basis for a more consistent, precise, and correct systemic KI model. Interesting alternatives seem Katz & Kahn's (1979) model of organizations as social systems, and Beer's (1971) cybernetic model of organizations. Both these models provide a different view on system functions than Parsons' theory. We expect that an explicit comparison of these different system theories can lead to a better understanding of KI as a system and as such to an improvement of the soundness of the systemic KI model. An example of how such comparison could be performed is by using Katz & Kahn's and Beer's typologies of system functions, transform them into definitions of KI system functions, propose patterns of KI activities that contribute to the functions, operationalize them into a survey instrument and test them together with a patterning of KI activities that is based on Parsons' theory in a quantitative study.

Concerning the relevance it was argued in the assessment of the manageability of the model that the current version of the model is probably not easily understood by practitioners and is not instantiated in a practically usable form. Hence, in order to really support KI problem solving in practice, the manageability of the model should further be improved. We believe this can best be done by transforming the model 1) into a method and software tool that it used periodically and 2) into a method and software tool that can be systematically incorporated into the system's routines.

Concerning the first, we believe the model should be transformed into a software tool for the analysis and diagnosis of KI problems. We can think of a standalone software product, but also of an online web-application. Such a tool should be based on a problem solving method that systematically leads its user through each of the seven characteristics to find out where a problem arises, why it is there, and how it can be solved. While we have made some suggestions for such a method in Subsection 6.4.3, further research is needed in order to fully develop such a method.

Concerning the second type of method and tool, the model should first be transformed into a method for the prevention of problems and consequently into a software tool that can support the method. As these steps also have been made for, for example, the already mentioned quality management models, we suggest to consider how these models were transformed into methods and tools. As these models are widely documented, we expect to find a large number of guidelines on how this can be done.

For the development of the two groups of instantiations we suggest to follow the methods of design-oriented research in which the instantiations are developed, implemented, and evaluated in practice (Hevner, March, & Park, 2004; March & Smith, 1995; Van Aken, 2004). The advantage of these methods compared to 'pure' information systems or software development, is the explicit feedback to theory that is incorporated in these methods. As such, the result of the development of the methods and tools is not only the method or tool itself, but also a feedback on the systemic KI model. One particular important aspect of this feedback concerns that software development provides a means to improve the consistency and precision of the model: in order to program the model into a software product, it should be consistent and precise, because, otherwise, the software will not function.

6.5.3 New Research Directions

While improving the soundness and relevance of the systemic KI model provides one way to facilitate the improvement of KI and KI-problem solving in practice, there also is additional research needed to enable further improvements. The systemic KI model has highlighted some opportunities for such research that will enhance the understanding of KI.

Firstly, the notion of functions that is incorporated in the systemic KI model can form a means to bridge the gap between individual, group, and organizational aspects of KI. While the existing conceptualizations of KI are relatively advanced with respect to the aggregation levels, they hardly provide insights in the differentiation of KI between individuals, between groups, and between organizations. That is, there is little knowledge about the division of labor with respect to KI. By suggesting three types of knowledge functions and four types of system functions, this study opens directions for further research towards a better understanding of the structure and dynamics of KI systems at various levels of aggregation. Such research should address questions like: How do the functions instantiate in practice? What types of knowledge do they produce? What interchanges take place between the functions? How do the functions evolve in the course of time? Do the functions learn from one another? Do the functions evolve at the same, or a different pace? We believe that the answer to such questions will advance the understanding of KI at various levels of aggregation and will help to improve KI in practice.

Secondly, we suggest to consider the relationship between the environment of a KI system, configurations (or archetypes) of KI systems, and performance of a KI system. While the current model is generally applicable, a KI configuration would be a particular instantiation of the seven characteristics in a particular context. Theoretically, all configurations of actors, technologies, KI activities, knowledge, and their connections would be possible. However, we expect that, in practice, the number of configurations is much more limited. Hence, we expect there can be found particular archetypes of KI systems. When such archetypes exist, practitioners can use them to improve KI more efficiently: such archetypes provide practitioners with less options to chose from and with guidelines as to what configurations seem to be effective. While the mere existence of certain KI configurations in practice is probably one indicator of their success, it is certainly not the only one. Thus, we also need ways to establish whether there is a relationship between KI configurations and effectiveness. Obviously, the SF model suggested above provides directions for research in this area since the four system functions are directly related to four types of effectiveness. As we expect that configurations are not equally effective in all situations, we suggest that further research also should consider the environmental conditions under which particular configurations can be effective. Examples of questions that need answers are: What KI configurations can we find in practice? In which situations do KI configurations appear? How effective are KI configurations and in which situations are they effective? Which of the seven characteristics is most defining for KI configurations? How do KI configurations evolve over time? In order to start answering these questions, we believe the work of Kim & Lannon (1996), Senge (1990), and Mintzberg (1979; 1983) will be useful.

Thirdly, the notion of KI as an aspectsystem opens new directions for further research as well. In this study, we have described a KI system as rather separate from other aspects of organizations. Of course, in practice, KI is strongly interlinked with these other aspects.

However, the idea of considering a KI system as something not necessarily similar to an organization, provides us with interesting new research questions. Examples are: Do KI systems exist longer or shorter than organizations? How and when are KI systems born and how and when do they die? How do KI systems develop in the course of time? How do KI systems move over organizations in the course of time? How do existing KI systems lead to the birth of new organizations? We believe that the answer to such questions will increase the understanding of how, for example, organizations develop as they bring in new people or technology or when people leave an organization. While, in these cases, people and technologies move between organizations, they might still remain part of the same KI system. As the questions mentioned above have, to our knowledge, not been explored yet, we suggest that research in this direction should start with some exploratory studies.

Finally, KI cannot only be improved by supporting the identification, explanation, and solution of KI problems or by controlling KI, but also by facilitating the actors that perform KI activities with the appropriate means. As we have argued in this thesis, this support can consist of information technologies and non-information technologies. While there is a lot of emphasis in the current literature on supporting KI by information technology, there is only little emphasis on supporting it with non-information technologies (see Chapter 2). This study has argued that both are necessary and present in the same KI system. When both information technologies and non-information technologies are considered as part of one system, this provides us with interesting new research questions. Examples are: Can information technologies and non-information technologies substitute one another? How are information technologies and non-information technologies complementary? What KI activities can be supported by information technologies and what KI activities by non-information technologies? Can we design more effective information systems by including non-information technologies in them? Also the answers to these final questions will hopefully be helpful for improving KI in practice.

REFERENCES

Ackerman, M. S., & Halverson, C. A. 2000. Reexamining Organizational Memory. *Communications of the ACM*, 43(1): 59-64.
Adriaans, P. W. 1996. *Data Mining*. Harlow: Addison-Wesley.
Agre, G. P. 1982. The Concept of Problem. *Educational Studies*, 13: 121-142.
Agre, P. 2003. Hierarchy and History in Simon's "Architecture of Complexity". *Journal of the Learning Sciences*, 12(3): 413-426.
Aguilar, F. J. 1967. *Scanning the Business Environment*. New York, London: The MacMillan Company.
Akgün, A. E., Lynn, G. S., & Byrne, J. C. 2003. Organizational Learning: A Socio-Cognitive Framework. *Human Relations*, 56(7): 839-868.
Alavi, M., & Leidner, D. E. 2001. Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues. *MIS Quarterly*, 25(1): 107-136.
Alavi, M., & Tiwana, A. 2002. Knowledge Integration in Virtual Teams: The Potential Role of KMS. *Journal of the American Society for Information Science and Technology*, 53(12): 1029-1037.
Albino, V., Garavelli, A. C., & Schiuma, G. 1999. Knowledge Transfer and Inter-firm Relationships in Industrial Districts: the Role of the Leader Firm. *Technovation*, 19: 53-63.
Alexander, J. 1983. *Theoretical Logic in Sociology. Vol. 4: The Modern Reconstruction of Classical Thought: Talcott Parsons*. London, Melbourne and Henley: Routledge & Kegan Paul.
Allen, B. 1996. *Information Tasks: Toward a User-Centered Approach to Information Systems*. San Diego: Academic Press.
Allen, T. J. 1977. *Managing the Flow of Technology* (sixth, 1993 ed.). Cambridge, Massachusetts: The MIT Press.
Allen, T. J., & Cohen, S. I. 1969. Information Flow in Research and Development Labatories. *Administrative Science Quarterly*, 14(1): 12-19.
Almeida, P. 1996. Knowledge Sourcing by Foreign Multinationals: Patent Citation Analysis in the U.S. Semiconductor Industry. *Strategic Management Journal*, 17(Winter): 155-165.
Almeida, P., & Kogut, B. 1999. Localization of Knowledge and the Mobility of Engineers in Regional Networks. *Management Science*, 45(7): 905-917.
Anand, V., Glick, W. H., & Manz, C. 2002. Thriving on the Knowledge of Outsiders: Tapping Organizational Social Capital. *Academy of Management Executive*, 15(1): 87-101.
Anderson, J. D., & Pérez-Carballo, J. 2001. The Nature of Indexing: How Humans and Machines Analyze Messages and Texts for Retrieval. Part I. Research, and the Nature of Human Indexing. *Information Processing & Management*, 37: 231-254.
Andersson, B.-E., & Nilsson, S.-G. 1964. Studies in the Reliability and Validity of the Critical Incident Technique. *Journal of Applied Psychology*, 48(6): 398-403.
Anzai, Y., & Simon, H. A. 1979. The Theory of Learning by Doing. *Psychological Review*, 86(2): 124-140.
Argote, L. 1999. *Organizational Learning: Creating, Retaining and Transferring Knowledge* (2000 ed.). Dordrecht, The Netherlands: Kluwer Academic Publisher Group.
Argote, L., Beckman, S. L., & Epple, D. 1990. The Persistence and Transfer of Learning in Industrial Settings. *Management Science*, 36(2): 140-154.
Argote, L., & Ingram, P. 2000. Knowledge Transfer: A Basis for Competitive Advantage in Firms. *Organizational Behavior and Human Decision Processes*, 82(1): 150-169.
Argote, L., McEvily, B., & Reagans, R. 2003. Managing Knowledge in Organizations: An Integrative Framework and Review of Emerging Themes. *Management Science*, 49(4): 571-582.
Argyris, C., Putnam, R., & McLain Smith, D. 1985. *Action Science*. San Francisco: Jossey-Bass.
Argyris, C., & Schön, D. A. 1978. *Organizational Learning: A Theory of Action Perspective*: Reading, MA: Addison-Wesley.
Ariely, D. 2000. Controlling the Information Flow: Effects on Consumers' Decision Making and Preferences. *Journal of Consumer Research*, 27(September): 233-248.

Armstrong, J. S., & Overton, T. S. 1977. Estimating Nonresponse Bias in Mail Surveys. *Journal of Marketing Research*, XIV(August): 396-402.
Ashby, W. R. 1956. *An Introduction to Cybernetics* (Internet (1999): http://pcp.vub.ac.be/books/IntroCyb.pdf ed.). London: Chapman & Hall.
Atherton, A. 2003. The Uncertainty of Knowing: An Analysis of the Nature of Knowledge in a Small Business Context. *Human Relations*, 56(11): 1379-1398.
Autio, E. 1994. New, Technology-based Firms as Agents of R&D and Innovation: An Empirical Study. *Technovation*, 14(4): 259-273.
AWT. 2003. Netwerken met Kennis: Kennisabsorptie en Kennisbenutting door Bedrijven. Den Haag.
AWT. 2004. Tijd om te Oogsten! Vernieuwing in het Innovatiebeleid. Den Haag: AWT.
Babby, E. 1995. *The Practice of Social Research* (7th ed.). Belmont, USA, etc.: Wadsworth Publishing Company.
Barrick, J. A., & Spilker, B. C. 2003. The Relations between Knowledge, Search Strategy, and Performance in Unaided and Aided Information Search. *Organizational Behavior and Human Decision Processes*, 90: 1-18.
Bates, M. J. 1979. Information Search Tactics. *Journal of the American Society for Information Science*, 30(4): 205-214.
Becerra-Fernandez, I., & Sabherwal, R. 2001. Organizational Knowledge Management: A Contingency Perspective. *Journal of Management Information Systems*, 18(1): 23-55.
Becker, M. C., & Zirpoli, F. 2003. Organizing New Product Development: Knowledge Hollowing-out and Knowledge Integration - The FIAT Auto Case. *International Journal of Operations & Production Management*, 23(9): 1033-1061.
Beer, S. 1972. *Brain of the Firm*. Chichester etc.: John Wiley & Sons.
Belkin, N. J., & Croft, W. B. 1992. Information Filtering and Information Retrieval: Two Sides of the Same Coin? *Communications of the ACM*, 35(12): 29-38.
Bell, D. G., Giordano, R., & Putz, P. 2002. Inter-firm Sharing of Process Knowledge: Exploring Knowledge Markets. *Knowledge and Process Management*, 9(1): 12-22.
Bertels, C. P., & Nauta, D. 1969. *Inleiding tot het Modelbegrip*. Bussum: Uitgeverij W. De Haan.
Bessant, J. 1999. The Rise and Fall of 'Supernet': A Case Study of Technology Transfer Policy for Smaller Firms. *Research Policy*, 28: 601-614.
Bessant, J., & Rush, H. 1995. Building Bridges for Innovation: The Role of Consultants in Technology Transfer. *Research Policy*, 24: 97-114.
Binney, D. 2001. The Knowledge Management Spectrum - Understanding the KM Landscape. *Journal of Knowledge Management*, 5(1): 33-42.
Blaauw, G. 2005. *Identificatie van Cruciale Kennis*. Ridderkerk: Labyrint Publications.
Blackler, F. 1995. Knowledge, Knowledge Work and Organizations: An Overview and Interpretation. *Organization Studies*, 16(6): 1021-1046.
Blain, R. R. 1970. A Critique of Parsons' Four Function Paradigm. *Sociological Quarterly* 11(Spring): 157-168.
Blain, R. R. 1971. An Alternative to Parsons' Four-Function Paradigm as a Basis for Developing General Sociological Theory. *American Sociological Review*, 36(4): 678-692.
Blau, P. M. 1964. *Exchange and Power in Social Life*. New York: Wiley.
Blecker, T., & Neumann, R. 2000. Interorganizational Knowledge Management: Some Perspectives for Knowledge Oriented Strategic Management in Virtual Organizations. In Y. Malhotra (Ed.), *Knowledge Management and Virtual Organizations*: 63-83. USA/UK: Idea Group Publishing.
Boari, C., & Lipparini, A. 1999. Networks Within Industrial Districts: Organising Knowledge Creation and Transfer by Means of Moderate Hierarchies. *Journal of Management and Governance*, 3: 339-360.
Boersma, J. S. K. T., & Stegwee, R. A. 1996. *Exploring the Issues in Knowledge Management*. Paper presented at the Information Resources Management Association International Conference, Washington DC.
Boisot, M. 1995. *Information Space: A Framework for Learning in Organizations, Institutions and Culture*. London: Routledge.

Boisot, M. 1998. *Knowledge Assets: Securing Competitive Advantage in the Information Economy*. Oxford (UK): Oxford University Press.
Borgman, C. L., Hirsh, S. G., Walter, V. A., & Gallagher, A. L. 1995. Children's Searching Behavior on Browsing and Keyword Online Catalogs: The Science Library Catalog Project. *Journal of the American Society for Information Science*, 46(9): 663-684.
Bougrain, F., & Haudeville, B. 2002. Innovation, Collaboration and SMEs Internal Research Capacities. *Research Policy*, 31: 735-747.
Boulding, K. E. 1956. General Systems Theory: The Skeleton of Science. *Management Science*, 2(3): 197-208.
Braganza, A., Edwards, C., & Lambert, R. 1999. A Taxonomy of Knowledge Projects to Underpin Organizational Innovation and Competitiveness. *Knowledge and Process Management*, 6(2): 83-90.
Bresman, H., Birkinshaw, J., & Nobel, R. 1999. Knowledge Transfer in International Acquisitions. *Journal of International Business Studies*, 30(3): 439-462.
Broun, K. 2004. New Dog, Old Trick: Alerts for RSS Feeds. *Library Journal*, 129(Summer): 18-20.
Brown, J. S., & Duguid, P. 2001. Knowledge and Organization: A Social-Practice Perspective. *Organization Science*, 12(2): 198-213.
Browne, G. J., & Rogich, M. B. 2001. An Empirical Investigation of User Requirements Elicitation: Comparing the Effectiveness of Prompting Techniques. *Journal of Management Information Systems*, 17(4): 223-249.
Bunge, M. 1998a. *Philosophy of Science: From Explanation to Justification* (2002 ed.). New Brunswick (USA): Transaction Publishers.
Bunge, M. 1998b. *Philosophy of Science: From Problem to Theory* (2002 ed.). New Brunswick (USA): Transaction Publishers.
Burnett, S., Brookes-Rooney, A., & Keogh, W. 2002. Brokering Knowledge in Organizational Networks: The SPN Approach. *Knowledge and Process Management*, 9(1): 1-11.
Byström, K., & Järvelin, K. 1995. Task Complexity Affects Information Seeking and Use. *Information Processing & Management*, 31(2): 191-213.
Campbell, D. T. 1955. The Informant in Quantitative Research. *American Journal of Sociology*, 60(4): 339-342.
Campbell, D. T., & Fiske, D. W. 1959. Convergent and Discriminant Validation by the Multitrait-Multimethod Matrix. *Psychological Bulletin*, 56(1): 81-105.
Carlile, P. R., & Rebentisch, E. S. 2003. Into the Black Box: The Knowledge Transformation Cycle. *Management Science*, 49(9): 1180-1195.
Case, D. O. 2002. *Looking for Information: A Survey of Research on Information Seeking, Needs, and Behavior*. San Diego, California: Academic Press.
Castells, M. 1996. *The Rise of the Network Society*. Oxford, UK: Blackwell Publishers.
Chaston, I., Badger, B., & Sadler-Smith, E. 2001. Organizational Learning: An Empirical Assessment of Process in Small U.K. Manufacturing Firms. *Journal of Small Business Management*, 39(2): 139-151.
Chell, E. 2004. Critical Incident Technique. In C. Cassell, & G. Symon (Eds.), *Essential Guide to Qualitative Methods in Organizational Research*: 45-60. London etc.: Sage Publications.
Chell, E., Haworth, J. M., & Brearley, S. 1991. *The Entrepreneurial Personality: Concepts, Cases and Categories*. London etc.: Routledge.
Chernilo, D. 2002. The Theorization of Social Co-ordination in Differentiated Societies: The Theory of Generalized Symbolic Media in Parsons, Luhmann and Habermas. *British Journal of Sociology*, 53(3): 431-449.
Choo, C. W. 1998. *The Knowing Organization*. New York, Oxford: Oxford University Press.
Choo, C. W. 2001. Environmental Scanning as Information Seeking and Organizational Learning. *Information Research*, 7(1 (Special Issue)).
Choo, C. W. 2002. *Information Management for the Intelligent Organization: The Art of Scanning the Environment*. Medford, New Jersey: Information Today, Inc.
Choo, C. W., Detlor, B., & Turnbull, D. 2000. *Web Work: Information Seeking and Knowledge Work on the World Wide Web*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Clancey, W. J. 1993. The Knowledge Level Reinterpreted: Modeling Socio-Technical Systems. *International Journal of Intelligent Systems*, 8: 33-49.
Clark, K. B., & Wheelwright, S. C. 1993. *Managing New Product and Process Development: Text and Cases*. New York: The Free Press.
Clemons, E. K., & Lang, K. R. 2003. The Decoupling of Value Creation from Revenue: A Strategic Analysis of the Markets for Pure Information Goods. *Information Technology and Management*, 4: 259-287.
Cohen, W. M., & Levinthal, D. A. 1990. Absorptive Capacity: a New Perspective on Learning and Innovation. *Administrative Science Quarterly*, 35(1): 128-152.
Cole, C. 1998. Intelligent Information Retrieval: Diagnosing Information Need. Part I. The Theoretical Framework for Developing and Intelligent IR Tool. *Information Processing & Management*, 34(6): 709-720.
Coleman, J. S. 1986. Social Theory, Social Research, and a Theory of Action. *American Journal of Sociology*, 91(6): 1309-1335.
Cook, T. D., & Campbell, D. T. 1979. *Quasi-Experimentation: Design & Analysis Issues for Field Settings*. Chicago: Rand McNally College Pub. Co.
Cooke, N. J. 1994. Varieties of Knowledge Elicitation Techniques. *International Journal of Human-Computer Studies*, 41: 801-849.
Cooper, D. R., & Schindler, P. S. 1998. *Business Research Methods* (6th ed.). Singapore: Irwin/McGraw-Hill.
Cooper, H. M. 1989. *Integrating Research: A Guide for Literature Reviews* (2nd ed.). Newbury Park, California: Sage Publications.
Cooper, R. G. 2001. *Winning at New Products: Accelerating the Process from Idea to Launch* (3rd ed.). Massachusetts: Perseus Books.
Corner, P. D., Kinicki, A. J., & Keats, B. W. 1994. Integrating Organizational and Individual Information Processing Perspectives on Choice. *Organization Science*, 5(3): 294-308.
Cronin, B., & Hert, C. A. 1995. Scholarly Foraging and Network Discovery Tools. *Journal of Documentation*, 51(4): 388-403.
Crossan, M. M., Lane, H. W., & White, R. E. 1999. An Organizational Learning Framework: From Intuition to Institution. *Academy of Management Review*, 24(3): 522-537.
D'Adderio, L. 2001. Crafting the Virtual Prototype: How Firms Integrate Knowledge and Capabilities Across Organisational Boundaries. *Research Policy*, 30(9): 1409-1424.
Daft, R. L., & Lengel, R. H. 1984. Information Richness: A New Approach to Managerial Behavior and Organizational Design. *Research in Organizational Behavior*: 191-233.
Daft, R. L., & Lengel, R. H. 1986. Organizational Information Requirements, Media Richness and Structural Design. *Management Science*, 32(5): 554-571.
Daft, R. L., Lengel, R. H., & Trevino, L. K. 1987. Message Equivocality, Media Selection and Manager Performance: Implications for Information Systems. *MIS Quarterly*, 11(3): 355-366.
Daft, R. L., & Weick, K. E. 1984. Toward a Model of Organizations as Interpretation Systems. *Academy of Management Review*, 9(2): 284-295.
Darlington, R. B. 2005. Factor Analysis: http://comp9.psych.cornell.edu/Darlington/factor.htm.
Davenport, T. H., & Völpel, S. C. 2001. The Rise of Knowledge Towards Attention Management. *Journal of Knowledge Management*, 5(3): 212-221.
Davidsson, P. 2004. *Researching Entrepreneurship*. Boston, etc.: Springer.
Davis, G. B. 1982. Strategies for Information Requirements Determination. *IBM Systems Journal*, 21(1): 4-30.
Davis, M. S. 1971. That's Interesting : Towards a Phenomenology of Sociology and a Sociology of Phenomenology. *Philosophy of the Social Sciences*, 1(4): 309-344.
De Boer, M., Van den Bosch, F. A. J., & Volberda, H. W. 1999. Managing Organizational Knowledge Integration in the Emerging Multimedia Complex. *Journal of Management Studies*, 36(3): 379-398.
De Leeuw, A. C. J. 1999. Kwaliteit van Bedrijfskundige Kennis: Kennisproducten en hun Bruikbaarheid. In M. J. Van Riemsdijk (Ed.), *Dilemma's in de Bedrijfskundige Wetenschap*: 185-205. Assen: Van Gorcum & Comp.

De Leeuw, A. C. J. 2000. *Bedrijfskundig Management: Primair Proces, Strategie en Organisatie*. Assen: Van Gorcum en Comp. BV.

De Leeuw, A. C. J., & Volberda, H. W. 1996. On the Concept of Flexibility: A Dual Control Perspective. *Omega*, 24(2): 121-139.

Denrell, J. 2003. Vicarious Learning, Undersampling of Failure, and the Myths of Management. *Organization Science*, 14(3): 227-243.

Dervin, B. 1992. From the Mind's Eye of the 'User': The Sense-Making Qualitative-Quantitative Methodology, *Qualitative Research in Information Management*: 61-84: Englewood, CO: Libraries Unlimited.

Devon, R., & Bush, L. 1996. Teaching Technology Decision Making for Product Design and Development: A University Course on Technology Assessment and Technology Transfer. *Journal of Technology Transfer*, 21(1-2): 16-21.

Dirksen, C. J., & Kroeger, A. 1960. *Advertising Principles and Problems*. Homewood: R.D. Irwin.

Dodd, J. B. 1996. Information Brokers. *Special Libraries*, Fall: 307-317.

Doll, W. J., & Torkzadeh, G. 1988. The Measurement of End-User Computing Satisfaction. *MIS Quarterly*, 12(2): 259-274.

Drucker, P. F. 1992. The New Society of Organizations. *Harvard Business Review*, 70(September-October): 95-104.

Dubin, R. 1978. *Theory Building* (Revised ed.). New York: The Free Press.

Duncan, W. J. 1972. The Knowledge Utilization Process in Management and Organization. *Academy of Management Journal*, 15(3): 273-287.

Dyer, J. H., & Nobeoka, K. 2000. Creating and Managing a High-Performance Knowledge-Sharing Network: The Toyota Case. *Strategic Management Journal*, 21: 345-367.

Easton, A. N., Price, J. H., Telljohann, S. K., & Boehm, K. 1997. An Informational Versus Monetary Incentive in Increasing Physicians' Response Rates. *Psychological Reports*, 81(3): 968-970.

Eisenhardt, K. M. 1989. Building Theories from Case Study Research. *Academy of Management Review*, 14(4): 532-550.

Ellis, D., & Haugan, M. 1997. Modeling the Information Seeking Patterns of Engineers and Research Scientists in an Industrial Environment. *Journal of Documentation*, 53(4): 384-403.

Ellis, D., Wilson, T. D., Ford, N., Lam, H. M., & Burton, R. 2002. Information Seeking and Mediated Searching. Part 5. User-Intermediary Interaction. *Journal of the American Society for Information Science and Technology*, 53(11): 883-893.

Emery, F. 1993. Characteristics of Socio-Technical Systems. In E. Trist, & H. Murray (Eds.), *The Social Engagement of Social Science Volume II: The Socio-Technical Perspective*: 157-186. Philadelphia: University of Pennsylvania Press.

Emery, F. E. (Ed.). 1969. *Systems Thinking*. Middlesex: Penguin Books.

Emery, F. E., & Trist, E. L. 1960. Socio-Technical Systems. In C. W. Churchman, & M. Verhulst (Eds.), *Management Sciences: Models and Techniques*, Vol. 2: 83-97. London: Pergamon.

Empson, L. 2001. Fear of Exploitation and Fear of Contamination: Impediments to Knowledge Transfer in Mergers Between Professional Service Firms. *Human Relations*, 54(7): 839-862.

Epple, D., Argote, L., & Devadas, R. 1991. Organizational Learning Curves: A Method for Investigating Intra-Plant Transfer of Knowledge Acquired Through Learning by Doing. *Organization Science*, 2(1): 58-70.

Erdelez, S. 1999. Information Encountering: It's More Than Just Bumping into Information. *Bulletin of the American Society for Information Science*, 25(3): 25-29.

Ericsson, K. A., & Simon, H. A. 1998. How to Study Thinking in Everyday Life: Contrasting Think-Aloud Protocols With Descriptions and Explanations of Thinking. *Mind, Culture, and Activity*, 5(3): 178-186.

European Commission. 1996. Commission Recommendation of 3 April 1996 Concerning the Definition of Small and Medium-Sized Enterprises. *Official Journal of the European Communities*(L 107): 4-9.

European Commission. 2002a. The European Observatory for SMEs: Sixth Report.

European Commission. 2002b. Observatory of European SMEs: High-tech SMEs in Europe.

European Commission. 2002c. Observatory of European SMEs: SMEs in Europe, Including a First Glance at EU Candidate Countries.
Eylon, B.-S. 2000. Designing Powerful Learning Environments and Practical Theories: The Knowledge Integration Environment. *International Journal of Science Education*, 22(8): 885-890.
Faran, D., Hauptman, A., & Raban, Y. 2005. Organizing the Toolbox: Typology and Alignment of KI Solutions. In A. Jetter, J. Kraaijenbrink, H.-H. Schröder, & F. Wijnhoven (Eds.), *Knowledge Integration: The Practice of Knowledge Management in Small and Medium Enterprises*: 47-64. Heidelberg: Physica-Verlag.
Faulkner, W., & Senker, J. 1995. *Knowledge Frontiers: Public Sector Research and Industrial Innovation in Biotechnology, Engineering Ceramics, and Parallel Computing*. Oxford: Clarendon Press.
Feldman, M. S., & Pentland, B. T. 2003. Reconceptualizing Organizational Routines as a Source of Flexibility and Change. *Administrative Science Quarterly*, 48(1): 94-118.
Festinger, L. 1962. *A Theory of Cognitive Dissonance*. Stanford, Ca: Stanford University Press.
Feyerabend, P. K. 1993. *Against Method*. London: Verso.
Fiol, C. M. 1994. Consensus, Diversity, and Learning in Organizations. *Organization Science*, 5(3): 403-420.
Fisher, S., & Oulton, T. 1999. The Critical Incident Technique in Library and Information Management Research. *Education for Information*, 17: 113-125.
Flanagan, J. C. 1954. The Critical Incident Technique. *Psychological Bulletin*, 51(4): 327-358.
Forsgren, R. A. 1989. Increasing Mail Survey Response Rates: Methods for Small Business Researchers. *Journal of Small Business Management*, 27(4): 61-66.
Foster, A. 2004. A Nonlinear Model of Information-Seeking Behavior. *Journal of the American Society for Information Science and Technology*, 55(3): 228-237.
Frenkel, M. 2005. The Politics of Translation: How State-Level Political Relations Affect the Cross-National Travel of Management Ideas. *Organization*, 12(2): 275-231.
Gaines, B. R. 2003. Organizational Knowledge Acquisition. Calgary, Canada: Knowledge Science Institute, University of Calgary.
Galbraith, J. R. 1974. Organization Design: An Information Processing View. *Interfaces*, 4(3): 28-36.
Galunic, D. C., & Rodan, S. 1998. Resource Combinations in the Firm: Knowledge Structures and the Potential for Schumpeterian Innovation. *Strategic Management Journal*, 19: 1193-1201.
Garson, D. G. 2005. Structural Equation Modeling: http://www2.chass.ncsu.edu/garson/pa765/structur.htm.
Garud, R., & Nayyar, P. R. 1994. Transformative Capacity: Continual Structuring by Intertemporal Technology Transfer. *Strategic Management Journal*, 15(5): 365-385.
Gershoff, A. D., Broniarczyk, S. M., & West, P. M. 2001. Recommendation or Evaluation? Task Sensitivity in Information Source Selection. *Journal of Consumer Research*, 28: 418-438.
Gerstberger, P. G., & Allen, T. J. 1968. Criteria Used by Research and Development Engineers in the Selection of an Information Source. *Journal of Applied Psychology*, 52(4): 272-279.
Geurts, P. A. T. M., & Roosendaal, H. E. 2001. Estimating the Direction of Innovative Change Based on Theory and Mixed Methods. *Quality & Quantity*, 35: 407-427.
Giddens, A. 1984. *The Constitution of Society: Outline of the Theory of Structuration*. Berkeley and Los Angeles: University of California Press.
Gilad, B., & Gilad, T. 1988. *The Business Intelligence System: A New Tool for Competitive Advantage*. New York: Amacom.
Gioia, D. A., & Manz, C. C. 1985. Linking Cognition and Behavior: A Script Processing Interpretation of Vicarious Learning. *Academy of Management Review*, 10(3): 527-539.
Glaser, B. G. 1978. *Theoretical Sensitivity: Advances in the Methodology of Grounded Theory*. Mill Valley, California: The Sociology Press.
Glaser, B. G. 1992. *Basics of Grounded Theory Analysis: Emergence vs. Forcing*. Mill Valley, CA: Sociology Press.
Glaser, B. G., & Strauss, A. L. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. New York: Aldine Publishing Company.
Gold, A. H., Malhotra, A., & Segars, A. H. 2001. Knowledge Management: An Organizational Capabilities Perspective. *Journal of Management Information Systems*, 18(1): 185-214.

Goldman, A. 1979. Publishing Activity in Marketing as an Indicator of its Structure and Disciplinary Boundaries. *Journal of Marketing Research*, 16: 485-494.
Gouldner, A. W. 1971. *The Coming Crisis of Western Sociology*. London: Heinemann.
Grant, R. M. 1996. Prospering in Dynamically-Competitive Environments: Organizational Capability as Knowledge Integration. *Organization Science*, 7(4): 375-387.
Gray, P. H. 2001. A Problem-Solving Perspective on Knowledge Management Practices. *Decision Support Systems*, 31: 87-102.
Gray, P. H., & Meister, D. B. 2004. Knowledge Sourcing Effectiveness. *Management Science*, 50(6): 821-834.
Gregan-Paxton, J., & John, D. R. 1997. Consumer Learning by Analogy: A Model of Internal Knowledge Transfer. *Journal of Consumer Research*, 24: 266-284.
Griffin, A., & Hauser, J. R. 1992. Patterns of Communication among Marketing, Engineering and Manufacturing: A Comparison between Two New Product Teams. *Management Science*, 38(3): 360-373.
Groen, A. J., De Weerd-Nederhof, P. C., Kerssens-van Drongelen, I. C., Badoux, R. A. J., & Olthuis, G. P. H. 2002. Creating and Justifying Research and Development Value: Scope, Scale, Skill and Social Networking of R&D. *Creativity and Innovation Management*, 11(1): 2-16.
Grünbacher, P., Halling, M., Biffl, S., Kitapci, H., & Boehm, B. W. 2004. Integrating Collaborative Processes and Quality Assurance Techniques: Experiences from Requirements Negotiation. *Journal of Management Information Systems*, 20(4): 9-29.
Gupta, A. K., & Govindarajan, V. 2000. Knowledge Flows Within Multinational Corporations. *Strategic Management Journal*, 21: 473-496.
Gupta, A. K., Raj, S. P., & Wilemon, D. 1985. The R&D-Marketing Interface in High-Technology Firms. *Journal of Product Innovation Management*, 2(12-24).
Habermas, J. 1987. *The Theory of Communicative Action Volume 2: Lifeworld and System: A Critique of Functionalist Reason*. Cambridge, UK: Polity Press.
Hamel, G. 1991. Competition for Competence and Inter-Partner Learning Within International Strategic Alliances. *Strategic Management Journal*, 12(Summer): 83-103.
Hannan, M. T., & Freeman, J. 1977. The Population Ecology of Organizations. *American Journal of Sociology*, 82(5): 929-964.
Hannan, M. T., & Freeman, J. 1984. Structural Inertia and Organizational Change. *American Sociological Review*, 49(2): 149-164.
Hansen, M. T. 1999. The Search-Transfer Problem: The Role of Weak Ties in Sharing Knowledge Across Organization Subunits. *Administrative Science Quarterly*, 44: 82-111.
Hansen, M. T. 2002. Knowledge Networks: Explaining Effective Knowledge Sharing in Multiunit Companies. *Organization Science*, 13(3): 232-248.
Hansen, M. T., Nohria, N., & Tierney, T. 1999. What's Your Strategy for Managing Knowledge? *Harvard Business Review*(March-April): 106-116.
Hargadon, A. B. 1998. Firms as Knowledge Brokers: Lessons in Pursuing Continuous Innovation. *California Management Review*, 40(3): 209-227.
Hargadon, A. B. 2002. Brokering Knowledge: Linking Learning and Innovation. *Research in Organizational Behavior*, 24: 41-85.
Hargadon, A. B. 2003. *How Breakthroughs Happen: The Surprising Truth About How Companies Innovate*. Boston, Massachusetts: Harvard Business School Press.
Hargadon, A. B., & Douglas, Y. 2001. When Innovations Meet Institutions: Edison and the Design of the Electric Light. *Administrative Science Quarterly*, 46: 476-501.
Hargadon, A. B., & Fanelli, A. 2002. Action and Possibility: Reconciling Dual Perspectives of Knowledge in Organizations. *Organization Science*, 13(3): 290-302.
Hargadon, A. B., & Sutton, R. I. 1997. Technology Brokering and Innovation in a Product Development Firm. *Administrative Science Quarterly*, 42(4): 716-749.
Hayek, F. A. 1945. The Use of Knowledge in Society. *The American Economic Review*, 35(4): 519-530.

Hedberg, B. 1981. How Organizations Learn and Unlearn. In P. C. Nystrom, & W. H. Starbuck (Eds.), *Handbook of Organizational Design, Vol I*: 8-27. New York: Oxford University Press.
Hedlund, G. 1994. A Model of Knowledge Management and the N-Form Corporation. *Strategic Management Journal*, 15(Summer): 73-90.
Heeter, C., & Greenberg, B. S. 1985. Profiling the Zappers. *Journal of Advertising Research*, 25(2): 15-19.
Henderson, R., & Clark, K. 1990. Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly*, 35: 9-30.
Hendriks, P. 1999. Why Share Knowledge? The Influence of ICT on the Motivation for Knowledge Sharing. *Knowledge and Process Management*, 6(2): 91-100.
Hertzberg, F. 1968. *Work and the Nature of Man*. London: Granada Publishing.
Hertzum, M., & Frøkjær, E. 1996. Browsing and Querying in Online Documentation: A Study of User Interfaces and the Interaction Process. *ACM Transactions on Human-Computer Interaction*, 3(2): 136-161.
Hevner, A. R., March, S. T., & Park, J. 2004. Design Science in Information Systems Research. *MIS Quarterly*, 28(1): 75-105.
Hickey, A. M., & Davis, A. M. 2004. A Unified Model of Requirements Elicitation. *Journal of Management Information Systems*, 20(4): 65-84.
Hinde, S. 2000. Smurfing, Swamping, Spamming, Spoofing, Squatting, Slandering, Surfing, Scamming and Other Mischiefs of the World Wide Web. *Computers & Security*, 19(4): 312-320.
Hirschheim, R., Klein, H. K., & Lyytinen, K. 1996. Exploring the Intellectual Structures of Information Systems Development: A Social Action Theoretic Analysis. *Accounting Management and Information Technologies*, 6(1/2): 1-64.
Hirschheim, R., & Lacity, M. 2000. The Myths and Realities of Information Technology Insourcing. *Communications of the ACM*, 43(2): 99-108.
Hofmeister, M. 1998. BatchKit: A Knowledge Integration Environment for Process Engineering. *Computers and Chemical Engineering*, 22(1-2): 109-146.
Holmqvist, M. 2004. Experiential Learning Processes of Exploitation and Exploration Within and Between Organizations: An Empirical Study of Product Development. *Organization Science*, 15(1).
Howells, J., James, A., & Malik, K. 2003. The Sourcing of Technological Knowledge: Distributed Innovation Processes and Dynamic Change. *R&D Management*, 33(4): 395-409.
Huang, J. C., & Newell, S. 2003. Knowledge Integration Processes and Dynamics Within the Context of Cross-Functional Projects. *International Journal of Project Management*, 21: 167-176.
Huang, J. C., Newell, S., & Pan, S.-L. 2001. The Process of Global Knowledge Integration: A Case Study of A Multinational Investment Bank's Y2K Program. *European Journal of Information Systems*, 10: 161-174.
Huang, X., Soutar, G. N., & Brown, A. 2002. New Product Development Processes in Small and Medium-Sized Enterprises: Some Australian Evidence. *Journal of Small Business Management*, 40(1): 27-42.
Huber, G. P. 1991. Organizational Learning: The Contributing Processes and the Literatures. *Organization Science*, 2(1): 88-115.
Hummel, M., Van Rossum, W., Omta, O., Verkerke, G., & Rakhorst, G. 2001. Types and Timing of Inter-organizational Communication in New Product Development. *Creativity and Innovation Management*, 10(4): 225-233.
Hutjes, J. M., & Van Buuren, J. A. 1992. *De Gevalsstudie: Strategie van Kwalitatief Onderzoek*. Meppel: Boom/Open Universiteit.
Iivari, J., Hirschheim, R., & Klein, H. K. 2004. Towards a Distinctive Body of Knowledge for Information Systems Experts: Coding ISD Process Knowledge in Two IS Journals. *Information Systems Journal*, 14: 313-342.
Inkpen, A. C. 1996. Creating Knowledge through Collaboration. *California Management Review*, 39(1): 123-140.
Inkpen, A. C., & Dinur, A. 1998. Knowledge Management Processes and International Joint Ventures. *Organization Science*, 9(4): 454-468.

Ivanitskaya, L., Clark, D., Montgomery, G., & Primeau, R. 2002. Interdisciplinary Learning: Process and Outcomes. *Innovative Higher Education*, 27(2): 95-111.
Jarvenpaa, S. L., & Staples, D. S. 2000. The Use of Collaborative Electronic Media for Information Sharing: An Exploratory Study of Determinants. *Journal of Strategic Information Systems*, 9: 129-154.
Jarvie, I. C. 1973. *Functionalism*. Minneapolis: Burgress Publishing Company.
Jassawalla, A. R., & Sashittal, H., C. 1998. An Examination of Collaboration in High-Technology New Product Development Processes. *Journal of Production and Innovation Management*, 15: 237-254.
Jetter, A., Kraaijenbrink, J., Schröder, H.-H., & Wijnhoven, F. 2005. *Knowledge Integration: The Practice of Knowledge Management in Small and Medium Enterprises*. Heidelberg: Physica-Verlag.
Jin, Y., & Sendhoff, B. 1999. Knowledge Incorporation into Neural Networks From Fuzzy Rules. *Neural Processing Letters*, 10(3): 231.
John, G., & Martin, J. 1984. Effects of Organizational Structure of Marketing Planning on Credibility and Utilization of Plan Output. *Journal of Marketing Research*, 21(2): 170-183.
Johnson, H. M. 1973. The Generalized Symbolic Media in Parsons' Theory. *Sociology and Social Research*, 57(2): 208-221.
Jones, M. 2000. Mission Impossible? Pluralism and 'Multi-Paradigm' IS Research. *Information Systems Review*, 1(1): 217-232.
Julien, P.-A. 1995. New Technologies and Technological Information in Small Businesses. *Journal of Business Venturing*, 10: 459-475.
Kahn, R. L., & Cannell, C. F. 1957. *The Dynamics of Interviewing: Theory, Technique, and Cases*. New York: Wiley.
Katz, D., & Kahn, R. L. 1966. *The Social Psychology of Organizations*. New York: John Wiley.
Katz, D., & Kahn, R. L. 1979. *The Social Psychology of Organizations*. New York etc. : John Wiley & Sons.
Keegan, W. J. 1974. Multinational Scanning: A Study of the Information Sources Utilized by Headquarters Executives in Multinational Companies. *Administrative Science Quarterly*, 19(3): 411-421.
Kerlinger, F. N. 1986. *Foundations of Behavioral Research* (3rd ed.). New York, etc.: Holt, Rinehart and Whinston.
Kim, D. H. 1993. The Link between Individual and Organizational Learning. *Sloan Management Review*, 35(1): 37-50.
Kim, D. H., & Lannon, C. P. 1996. *Applying Systems Archetypes* Pegasus Communications.
King, G., Keohane, R. O., & Verba, S. 1994. *Designing Social Inquiry: Scientific Inference in Qualitative Research*. Princeton NJ: Princeton University Press.
Knight, L. 2002. Network Learning: Exploring Learning by Interorganizational Networks. *Human Relations*, 55(427-454).
Knott, A. M., Bryce, D. J., & Posen, H. E. 2003. On the Strategic Accumulation of Intangible Assets. *Organization Science*, 14(2): 192-207.
Kogut, B. 2000. The Network as Knowledge: Generative Rules and the Emergence of Structure. *Strategic Management Journal*, 21: 405-425.
Kogut, B., & Zander, U. 1992. Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology. *Organization Science*, 3(3): 383-397.
Kolb, D. A. 1976. Management and the Learning Process. *California Management Review*, 18(3): 21-31.
Kolb, D. A. 1984. *Experiental Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice-Hall.
Kraaijenbrink, J. 2003. *Toward a Conditional Design Theory for Electronic Knowledge Brokers*. Paper presented at the FGWM 2003 Workshop, 6-8 October, Karlsruhe.
Kraaijenbrink, J. 2005a. *Do Knowledge Sources Matter? Exploring the Effect of Knowledge Sources on Knowledge Integration Processes*. Paper presented at the European Conference on Organizational Knowledge, Learning, and Capabilities, Boston.
Kraaijenbrink, J. 2005b. *Towards a Classification Framework of External Knowledge Integration Processes*. Paper presented at the Annual Meeting of the Academy of Management, Honolulu, Hawaii.

Kraaijenbrink, J., Faran, D., & Hauptman, A. 2005. Knowledge Integration by SMEs - Framework. In A. Jetter, J. Kraaijenbrink, H.-H. Schröder, & F. Wijnhoven (Eds.), *Knowledge Integration: The Practice of Knowledge Management in Small and Medium Enterprises*: 17-28. Heidelberg: Physica-Verlag.
Kraaijenbrink, J., Groen, A., & Wijnhoven, F. 2005. Knowledge Integration by SMEs - Practice. In A. Jetter, J. Kraaijenbrink, H.-H. Schröder, & F. Wijnhoven (Eds.), *Knowledge Integration: The Practice of Knowledge Management in Small and Medium Enterprises*: 29-46. Heidelberg: Physica Verlag.
Kraaijenbrink, J., & Wijnhoven, F. 2006. External Knowledge Integration. In D. G. Schwartz (Ed.), *Encyclopedia of Knowledge Management*: 180-187. Hershey, etc.: Idea Group Reference.
Kraaijenbrink, J., Wijnhoven, F., & Groen, A. 2003. Data Collection & Analysis; Scientific Report on KI in Practice. Enschede: GROWTH Project No G1RD-CT-2002-00700: Knowledge Integration and Network eXpertise (KINX).
Kraatz, M. S. 1998. Learning by Association? Interorganizational Networks and Adaptation to Environmental Change. *Academy of Management Journal*, 41(6): 621-643.
Krikelas, J. 1983. Information-Seeking Behavior: Patterns and Concepts. *Drexel Library Quarterly*, 19(2): 5-20.
Kuhn, T. 1996. *The Structure of Scientific Revolutions* (3rd ed.). Chicago and London: The University of Chicago Press.
Kulthau, C. C. 1991. Inside the Search Process: Information Seeking from the User's Perspective. *Journal of the American Society for Information Science*, 42(5): 361-371.
Kulthau, C. C. 1993. *Seeking Meaning: A Process Approach to Library and Information Services*. Norwood: Ablex Publishing.
Kumar, N., Stern, L. W., & Anderson, J. C. 1993. Conducting Interorganizational Research Using Key Informants. *Academy of Management Journal*, 36(6): 1633-1651.
Künzler, J. 1989. *Medien und Gesellschaft: Die Medienkonzepte von Talcott Parsons, Jürgen Habermas und Niklas Luhmann*. Stuttgart: Ferdinand Enke Verlag.
Kwasitsu, L. 2003. Information-Seeking Behavior of Design, Process, and Manufacturing Engineers. *Library & Information Science Research*, 25: 459-476.
Lakatos, I. 1970. Falsification and the Methodology of Scientific Research Programmes. In I. Lakatos, & A. Musgrave (Eds.), *Criticism and the Growth of Knowledge*. Cambridge: Cambridge University Press.
Lam, A. 2000. Tacit Knowledge, Organizational Learning and Societal Institutions: An Integrated Framework. *Organization Studies*, 21(3): 487-513.
Lane, P. J., & Lubatkin, M. 1998. Relative Absorptive Capacity and Interorganizational Learning. *Strategic Management Journal*, 19: 461-477.
Länsisalmi, H., Peiró, J.-M., & Kivimäki, M. 2004. Grounded Theory in Organizational Research. In C. Cassell, & G. Symon (Eds.), *Essential Guide to Qualitative Methods in Organizational Research*: 242-255. London etc.: Sage Publications.
Larsson, R., Bengtsson, L., Henriksson, K., & Sparks, J. 1998. The Interorganizational Learning Dilemma: Collective Knowledge Development in Strategic Alliances. *Organization Science*, 9(3): 285-305.
Latour, B. 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory* Oxford: Oxford University Press.
Laurel, B. 2003. *Design Research: Methods and Perspectives*. Cambridge, Massachusetts; London England: The MIT Press.
Leckie, G. J., Pettigrew, K. E., & Sylvain, C. 1996. Modeling the Information Seeking of Professionals: A General Model Derived from Research on Engineers, Health Care Professionals and Lawyers. *Library Quarterly*, 66: 161-193.
Lee, A. S. 1991. Integrating Positivist and Interpretive Approaches to Organizational Research. *Organization Science*, 2(4): 342-365.
Lee, A. S., & Baskerville, R. L. 2003. Generalizing Generalizability in Information Systems Research. *Information Systems Research*, 14(3): 221-243.
Lee, G. K., & Cole, R. E. 2003. From a Firm-Based to a Community-Based Model of Knowledge Creation: The Case of the Linux Kernel Development. *Organization Science*, 14(6): 633-649.

Lee, J.-N. 2001. The Impact of Knowledge Sharing, Organizational Capability and Partnership Quality on IS Outsourcing Success. *Information & Management*, 38: 323-335.

Lee, K. C., Han, J. H., Song, Y. U., & Lee, W. J. 1998. A Fuzzy Logic-driven Multiple Knowledge Integration Framework for Improving the Performance of Expert Systems. *International Journal of Intelligent Systems in Accounting, Finance & Management*, 7(4): 213-222.

Leonard, D., & Sensiper, S. 1998. The Role of Tacit Knowledge in Group Innovation. *California Management Review*, 40(3): 112-132.

Levin, I. P., Huneke, M. E., & Jasper, J. D. 2000. Information Processing at Successive Stages of Decision Making: Need for Cognition and Inclusion-Exclusion Effects. *Organizational Behavior and Human Decision Processes*, 82(2): 171-193.

Levine, L. 2001. Integrating Knowledge and Processes in a Learning Organization. *Information Systems Management*(Winter): 21-33.

Levitt, B., & March, J. G. 1988. Organizational Learning. *Annual Review of Sociology*, 14: 319-340.

Liebeskind, J. P., Oliver, A. L., Lynne, Z., & Marilynn, B. 1996. Social Networks, Learning, and Flexibility: Sourcing Scientific Knowledge in New Biotechnology Firms. *Organization Science*, 7(4): 428-443.

Lilienfeld, R. 1978. *The Rise of Systems Theory*. New York: John Wiley.

Lockwood, D. 1956. Some Remarks on "The Social System". *British Journal of Sociology*, 7(2): 134-146.

Loebbecke, C., & Van Fenema, P. C. 2000. Virtual Organizations that Cooperate and Compete: Managing the Risks of Knowledge Exchange. In Y. Malhotra (Ed.), *Knowledge Management and Virtual Organizations*: 162-180. USA UK: Idea Group Publisher.

Lord, M. D., & Ranft, A. L. 2000. Organizational Learning about New International Markets: Exploring the Internal Transfer of Local Market Knowledge. *Journal of International Business Studies*, 31(4): 573-589.

Lord, R. G., & Maher, K. J. 1990. Alternative Information-Processing Models and Their Implications for Theory, Research, and Practice. *Academy of Management Review*, 15(1): 9-28.

Loucopoulos, P., & Karakostas, V. 1995. *System Requirements Engineering*. London: McGraw Hill Book Comp.

Lu, Y. 1996. Knowledge Integration in a Multiple Classifier System. *Applied Intelligence*, 6(2): 75-86.

Luhmann, N. 1977. Generalized Media and the Problem of Contingency. In J. Loubser, R. Baum, A. Effrat, & V. Lidz (Eds.), *Explorations in the General Theory of Social Science: Essays in the honour of Talcott Parsons*, Vol. 2. New York: Free Press.

Luhmann, N. 1995. *Social Systems*. Stanford: Stanford University Press.

Lyles, M. A., & Salk, J. E. 1996. Knowledge Acquisition from Foreign Parents in International Joint Ventures: An empirical Examination in the Hungarian Context. *Journal of International Business Studies*, 27(5): 877-903.

Lyons, K. L. 2000. Using Patterns to Capture Tacit Knowledge and Enhance Knowledge Transfer in Virtual Teams. In Y. Malhotra (Ed.), *Knowledge Management and Virtual Organizations*: 124-143. USA UK: Idea Group Publishing.

MacMullin, S. E., & Taylor, R. S. 1984. Problem Dimensions and Information Traits. *The Information Society*, 3(1): 91-111.

Madhavan, R., & Grover, R. 1998. From Embedded Knowledge to Embodied Knowledge: New Product Development as Knowledge Management. *Journal of Marketing*, 62: 1-12.

Majchrzak, A., Cooper, L. P., & Neece, O. E. 2004. Knowledge Reuse for Innovation. *Management Science*, 50(2): 174-188.

Majchrzak, A., Rice, R. E., King, N., Malhotra, A., & Ba, S. 2002. Computer-Mediated Inter-Organizational Knowledge-Sharing: Insights From a Virtual Team Innovating Using a Collaborative Tool. *Information Resources Management Journal*, 13(1): 44-53.

March, J. G. 1991. Exploration and Exploitation in Organizational Learning. *Organization Science*, 2(1): 71-87.

March, J. G., & Simon, H. A. 1958. *Organizations*. New York etc.: John Wiley.

March, S. T., & Smith, G. F. 1995. Design and Natural Science Research on Information Technology. *Decision Support Systems*, 15: 251-266.

Marchionini, G. 1995. *Information Seeking in Electronic Environments*. Cambridge: Cambridge University Press.

Markus, M. L. 2001. Toward a Theory of Knowledge Reuse: Types of Knowledge Reuse Situations and Factors in Reuse Success. *Journal of Management Information Systems*, 18(1): 57-93.

Markus, M. L., Majchrzak, A., & Gasser, L. 2002. A Design Theory for Systems That Support Emergent Knowledge Processes. *MIS Quarterly*, 26(3): 179-212.

Maslow, A. H. 1970. *Motivation and Personality* (2nd ed.). New York: Harper & Row.

Maturana, H. R., & Varela, F. G. 1992. *The Tree of Knowledge: The Biological Roots of Human Understanding*. Boston: Shambhala.

McCardle, K. F. 1985. Information Acquisition and the Adoption of New Technology. *Management Science*, 31(11): 1372-1389.

McEvily, S. K., Das, S., & McCabe, K. 2000. Avoiding Competence Substitution Through Knowledge Sharing. *Academy of Management Review*, 25(2): 294-311.

McKay, J., & Marshall, P. 2000. The Challenges of Interorganisational Management: An Emerging Issue in the Virtual Organization. In D. G. Schwartz, M. Divitini, & T. Brasethvik (Eds.), *Internet-Based Organizational Memory and Knowledge Management*: 201-221. Hershey, USA; London UK: Idea Group Publishing.

McKeown, P. G., & Leitch, R. A. 1993. *Management Information Systems: Managing with Computers*. Fort Worth etc.: The Dryden Press.

McLure Wasko, M., & Faraj, S. 2000. "It Is What One Does": Why People Participate and Help Others in Electronic Communities of Practice. *Strategic Information Systems*, 9: 155-173.

McLure Wasko, M., & Faraj, S. 2005. Why Should I Share? Examining Social Capital and Knowledge Contribution in Electronic Networks of Practice. *MIS Quarterly*, 29(1): 35-57.

Meeus, M. T. H., Oerlemans, L. A. G., & Hage, J. 2001. Patterns of Interactive Learning in a High-Tech Region. *Organization Studies*, 22(1): 145-172.

Menon, A., & Varadarajan, P. R. 1992. A Model of Marketing Knowledge Use Within Firms. *Journal of Marketing*, 56(October): 53-71.

Merton, R. K. 1967. *On Theoretical Sociology: Five Essays, Old and New*. Toronto: Collier-Macmillan Canada Ltd.

Merton, R. K. 1968. *Social Theory and Social Structure* (revised and enlarged ed.). New York: The Free Press.

Meyer, M. H., & Zack, M. H. 1996. The Design and Development of Information Products. *Sloan Management Review*, 37(3): 43-59.

Miles, M. B., & Huberman, A. M. 1994. *Qualitative Data Analysis: An Expanded Sourcebook* (Second ed.). London: Sage Publications.

Milton, N., Shadbolt, N., Cottam, H., & Hammersley, M. 1999. Towards a Knowledge Technology for Knowledge Management. *International Journal of Human-Computer Studies*, 51: 615-641.

Mingers, J. 2001. Combining IS Research Methods: Towards a Pluralist Methodology. *Information Systems Research*, 12(3): 240-259.

Mintzberg, H. 1979. *The Structuring of Organizations: A Synthesis of the Research*. Englewood Cliffs, N.J.: Prentice-Hall, Inc.

Mintzberg, H. 1983. *Structure in Fives: Designing Effective Organizations*. Englewood Cliffs, N.J.: Prentice-Hall.

Mitchell, V.-W. 1994. Using Industrial Key Informants: Some Guidelines. *Journal of the Market Research Society*, 36(2): 139-144.

Moenaert, R. K., & Souder, W. E. 1996. Context and Antecedents of Information Utility at the R&D/Marketing Interface. *Management Science*, 42(11): 1592-1610.

Moorman, C. 1995. Organizational Market Information Processes: Cultural Antecedents and New Product Outcomes. *Journal of Marketing Research*, 32(3): 318-335.

Morgan, G. 1986. *Images of Organization*. New Delhi: Sage Publications.

Mowery, D. C., Oxley, J. E., & Silverman, B. S. 1996. Strategic Alliances and Interfirm Knowledge Transfer. *Strategic Management Journal*, 17(Winter): 77-91.

Muller, E., & Zenker, A. 2001. Business Services as Actors of Knowledge Transformation: The Role of KIBS in Regional and National Innovation Systems. *Research Policy*, 30: 1501-1516.

Murray, K. S. 1995. *Learning as Knowledge Integration*. The University of Texas at Austin, Austin.

Murray, P., & Myers, A. 1998. Survey of KM Practice in Europe, *Information Strategy Magazine*.

Nadler, D. A., & Tushman, M. L. 1988. *Strategic Organization Design: Concepts, Tools and Processes*. London: Scott, Foresman and Co.

Nelson, P. 1970. Information and Consumer Behavior. *The Journal of Political Economy*, 78(2): 311-329.

Nelson, R. R., & Winter, S. G. 1982. *An Evolutionary Theory of Economic Change*. Cambridge Massachusetts, London England: The Belknap Press of Harvard University Press.

Nissen, M., Kamel, M., & Sengupta, K. 2000. Integrated Analysis of Design of Knowledge Systems and Processes. *Information Resources Management Journal*, 13(1): 24-43.

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

Nooteboom, B. 1989. Diffusion, Uncertainty and Firm Size. *International Journal of Research in Marketing*, 6: 109-128.

Nunamaker Jr., J. F., Chen, M., & Purdin, T. D. M. 1990-91. Systems Development in Information Systems Research. *Journal of Management Information Systems*, 7(3): 89-106.

Oates, D. 1998. *Outsourcing and the Virtual Organization: The Incredible Shrinking Company*. London: Century Business.

OECD. 2001. Science, Technology and Industry Scoreboard 2001: Towards a Knowledge-Based Economy (e-Book).

Ogden, C. K., & Richards, I. A. 1949. *The Meaning of Meaning* (10th ed.). London: Routledge & Kegan Paul.

Okhuysen, G. A., & Eisenhardt, K. M. 2002. Integrating Knowledge in Groups: How Formal Interventions Enable Flexibility. *Organization Science*, 13(4): 370-386.

Olson, E. M., Walker Jr., O. C., Ruekert, R. W., & Bonner, J. M. 2001. Patterns of Cooperation During New Product Development Among Marketing, Operations and R&D: Implications for Project Performance. *The Journal of Product Innovation Management*, 18: 258-271.

Osborn, A. F. 1953. *Applied Imagination: Principles and Procedures of Creative Problem-Solving* (3rd rev. 1979 ed.). New York: Charles Scribner.

Osterloh, M., & Frey, B. S. 2000. Motivation, Knowledge Transfer, and Organizational Forms. *Organization Science*, 11(5): 538-550.

Pahl, G., & Beitz, W. 1996. *Engineering Design: A Systematic Approach*. London: Springer-Verlag.

Parsons, T. 1937. *The Structure of Social Action: A Study in Social Theory with Special Reference to a Group of Recent European Writers* (1961 ed.). New York: The Free Press of Glencoe.

Parsons, T. 1956a. Suggestions for a Sociological Approach to the Theory of Organizations. I. *Administrative Science Quarterly*, 1(1): 63-85.

Parsons, T. 1956b. Suggestions for a Sociological Approach to the Theory of Organizations. II. *Administrative Science Quarterly*, 1(2): 225-239.

Parsons, T. 1959. General Theory in Sociology. In R. Merton, L. Broom, & L. S. Cotrell Jr. (Eds.), *Sociology Today: Problems and Prospects*: 3-37. New York: Basic Books.

Parsons, T. 1961. An Outline of the Social System. In T. Parsons, E. Shils, K. D. Naegele, & J. Pitts (Eds.), *Theories of Society: Foundations of Modern Sociological Theory, Volume I*: 30-79. New York: The Free Press of Glencoe.

Parsons, T. 1964. *The Social System*. New York: The Free Press.

Parsons, T. 1977. *Social Systems and the Evolution of Action Theory*. New York: The Free Press.

Parsons, T., & Mayhew, L. H. 1982. *Talcott Parsons on Institutions and Social Evolution*. Chicago, London: University or Chicago Press.

Parsons, T., Shils, E., Naegele, K. D., & Pitts, J. (Eds.). 1961. *Theories of Society: Foundations of Modern Sociological Theory, Volume I*. New York: The Free Press of Glencoe.

Parsons, T., & Smelser, N. J. 1956. *Economy and Society: A Study in the Integration of Economic and Social Theory*. London: Routledge & Kegan Paul Ltd.
Paton, N. W., Goble, C. A., & Bechhofer, S. 2000. Knowledge Based Information Integration Systems. *Information and Software Technology*, 42: 299-312.
Patton, M. Q. 1978. *Utilization-Focused Evaluation*. Beverly Hills etc.: Sage Publications.
Peirce, C. S., Hartshorne, C., Weiss, P., & Burks, A. W. 1931-. *Collected Papers of Charles Sanders Peirce*. Cambridge: Harvard University Press.
Peli, G., Bruggeman, J., Masuch, M., & O'Nuallain, B. 1994. A Logical Approach to Formalizing Organizational Ecology. *American Sociological Review*, 59(4): 571-593.
Pentland, B. T. 1995. Information Systems and Organizational Learning: The Social Epistemology of Organizational Knowledge Systems. *Accounting Management and Information Technologies*, 5(1): 1-21.
Perse, E. M. 1990. Audience Selectivity and Involvement in the Newer Media. *Communication Research*, 17(5): 675-697.
Pham, M. T., & Johar, G. V. 1997. Contingent Process of Source Identification. *Journal of Consumer Research*, 24(239-265).
Pirolli, P., & Card, S. 1999. Information Foraging. *Psychological Review*, 106(4): 643-675.
Polanyi, M. 1966. *The Tacit Dimension*. London: Cox & Wyman Ltd.
Popper, K. 1959. *The Logic of Scientific Discovery* (2004 ed.). London, New York: Routledge Classics.
Popper, K. R. 1963. *Conjectures and Refutations*. London: Routledge & Kegan Paul.
Postrel, S. 2002. Islands of Shared Knowledge: Specialization and Mutual Understanding in Problem-Solving Teams. *Organization Science*, 13(3): 303-320.
Powell, W. W., Koput, K. W., & Smith-Doerr, L. 1996. Interorganizational Collaboration and the Locus of Innovation: Networks of Learning in Biotechnology. *Administrative Science Quarterly*, 41(1): 116-145.
Preece, A. e. a. 2000. The KRAFT Architecture for Knowledge Fusion and Transformation. *Knowledge-Based Systems*, 13: 113-120.
Proper, H. A., & Bruza, P. D. 1999. What is Information Discovery About? *Journal of the American Society for Information Science*, 50(9): 737-750.
Putnam, L. L., Phillips, N., & Chapman, P. 1996. Metaphors of Communication and Organization. In S. R. Clegg, C. Hardy, & W. R. Nord (Eds.), *Handbook of Organization Studies*. London/Thousand Oaks/New Dehli: SAGE Publications.
Quinn, J. B. 1992. *Intelligent Enterprise: A Knowledge and Service Based Paradigm for Industry*. New York: The Free Press.
Quinn, R. E., & Rohrbaugh, J. 1983. A Spatial Model of Effectiveness Criteria: Towards a Competing Values Approach to Organizational Analysis. *Management Science*, 29(3): 363-377.
Ramesh, B., & Tiwana, A. 1999. Supporting Collaborative Process Knowledge Management in New Product Development Teams. *Decision Support Systems*, 27: 213-235.
Ranft, A. L., & Lord, M. D. 2002. Acquiring New Technologies and Capabilities: A Grounded Model of Acquisition Implementation. *Organization Science*, 13(4): 420-441.
Ravasi, D., & Verona, G. 2001. Organising the Process of Knowledge Integration: The Benefits of Structural Ambiguity. *Scandinavian Journal of Management*, 17: 41-66.
Raymond, L., Julien, P.-A., & Ramangalahy, C. 2001. Technological Scanning by Small Canadian Manufacturers. *Journal of Small Business Management*, 39(2): 123-138.
Remus, U., & Schub, S. 2003. A Blueprint for the Implementation of Process-oriented Knowledge Management. *Knowledge and Process Management*, 10(4): 237-253.
Ring, P. S., & Van de Ven, A. H. 1994. Developmental Processes of Cooperative Interorganizational Relationships. *Academy of Management Review*, 19(1): 90-118.
Rivkin, J. W. 2001. Reproducing Knowledge: Replication Without Imitation at Moderate Complexity. *Organization Science*, 12(3): 274-293.
Robinson, P. 1995. Attention, Memory, and the 'Noticing' Hypothesis. *Language Learning*, 45(2): 283-332.
Rogers, E. M. 1983. *Diffusion of Innovations* (4th ed.). New York: The Free Press.

Rosenbloom, R. S., & Wolek, F. W. 1967. Technology, Information, and Organization: Information Transfer in Industrial R and D: US Department of Commerce / National Bureau of Standards / Institute for Applied Technology.

Rosenkopf, L., & Nerkar, A. 2001. Beyond Local Search: Boundary-Spanning, Exploration, and Impact in the Optical Disk Industry. *Strategic Management Journal*, 22: 287-306.

Ross, C. S. 1999. Finding Without Seeking: The Information Encounter in the Context of Reading for Pleasure. *Information Processing & Management*, 35: 783-799.

Ross Jr., W. T., & Creyer, E. H. 1992. Making Inferences About Missing Information: The Effects of Existing Information. *Journal of Consumer Research*, 19(1): 14-25.

Roth, K. 1982. *Konstruieren mit Konstruktionskatalogen: Systematisiering und Zweckmäßige Aufbereitung Technischer Sachverhalte für das Methodische Konstruieren*. Berlin Heidelberg New York: Springer-Verlag.

Rothwell, R. 1994. Industrial Innovation: Success, Strategy, Trends. In R. Rothwell, & M. Dodgson (Eds.), *The Handbook of Industrial Innovation*, Paperback 1996 ed.: 33-53. Cheltenham, UK, Brookfield, US: Edward Elgar Publishing Limited.

Rothwell, R., & Dodgson, M. 1994. Innovation and Size of Firm. In M. Dodgson, & R. Rothwell (Eds.), *The Handbook of Industrial Innovation*, Paperback 1996 ed.: 310-324. Cheltenham, UK, Brookfield, US: Edward Elgar Publishing Limited.

Ruggles, R. 1998. The State of the Notion: Knowledge Management in Practice. *California Management Review*, 40(3): 80-89.

Ryle, G. 1949. *The Concept of Mind* (1986 ed.). Harmondsworth: Penguin Books Ltd.

Santoro, M. D., & Gopalakrishnan, S. 2000. The Institutionalization of Knowledge Transfer Activities Within Industry-University Collaborative Ventures. *Journal of Engineering and Technology Management*, 17: 299-319.

Savage, S. P. 1981. *The Theories of Talcott Parsons: The Social Relations of Action*. London: MacMillan Press.

Scarborough, N. M., & Zimmerer, T. W. 2000. *Effective Small Business Management* (6th ed.). New Jersey: Prentice Hall.

Scharl, A., Gebauer, J., & Bauer, C. 2001. Matching Process Requirements with Information Technology to Assess the Efficiency of Web Information Systems. *Information Technology and Management*, 2: 193-210.

Scholz, R. W., Mieg, H. A., & Oswald, J. E. 2000. Transdisciplinarity in Groundwater Management: Towards Mutual Learning of Science and Society. *Water, Air and Soil Pollution*, 123(1/4): 477-487.

Schultze, U., & Orlikowski, W. 2004. A Practice Perspective on Technology-Mediated Network Relations: The Use of Internet-Based Self-Serve Technologies. *Information Systems Research*, 15(1): 87-106.

Schumpeter, J. A. 1934. *The Theory of Economic Development*. Cambridge, MA: Harvard University Press.

Schwabe, G. 1999. *Understanding and Supporting Knowledge Management and Organizational Memory in a City Council*. Paper presented at the Proceedings of the 32nd Hawaii International Conference on System Sciences.

Schwartz, D. G., Divitini, M., & Brasethvik, T. (Eds.). 2000. *Internet-Based Organizational Memory and Knowledge Management*. Hershey, USA; London, UK: Idea Group Publishing.

Selznick, P. 1948. Foundations of the Theory of Organization. *American Sociological Review*, 13(1): 25-35.

Senge, P. 1990. *The Fifth Discipline: The Art and Practice of the Learning Organization*. New York: Doubleday Currency.

Shannon, C. E., & Weaver, W. 1949. *The Mathematical Theory of Communication*. Urbana, Chicago, London: University of Illinois Press.

Shaw, M. J., Subramaniam, C., Tan, G. W., & Welge, M. E. 2001. Knowledge Management and Data Mining for Marketing. *Decision Support Systems*, 31: 127-137.

Shuchman, H. L. 1981. Information Transfer in Engineering. Glastonbury, CT: The Futures Group.

Simon, H. A. 1996. *The Sciences of the Artificial* (3rd ed.). Cambridge: The MIT Press.

Simon, H. A. 1997. *Administrative Behavior: A Study of Decision-Making Processes in Administrative Organizations* (4th ed.). New York: The Free Press.

Skyttner, L. 1998. The Future of Systems Thinking. *Systemic Practice and Action Research*, 11(2): 193-205.

Slone, D. J. 2003. Internet Search Approaches: The Influence of Age, Search Goals, and Experience. *Library & Information Science Research*, 25: 403-418.
Smeltzer, L. R., Fann, G. L., & Nikolaisen, V. N. 1988. Environmental Scanning Practices in Small Business. *Journal of Small Business Management*, 26(3): 55-62.
Smith, G. F. 1989. Defining Managerial Problems: A Framework for Prescriptive Theorizing. *Management Science*, 35(8): 963-981.
Soh, P.-H. 2003. The Role of Networking Alliances in Information Acquisition and its Implications for New Product Performance. *Journal of Business Venturing*, 18: 727-744.
Song, J., Almeida, P., & Wu, G. 2003. Learning-by-Hiring: When is Mobility More Likely to Facilitate Interfirm Knowledge Transfer. *Management Science*, 49(4): 351-365.
Song, X. M., Montoya-Weiss, M. M., & Schmidt, J. B. 1997. Antecedents and Consequences of Cross-Functional Cooperation: A Comparison of R&D, Manufacturing and Marketing Perspectives. *Journal of Product Innovation Management*, 14: 35-47.
Sowa, J. F. 2000. Ontology, Metadata, and Semiotics. In B. Ganter, & G. W. Mineau (Eds.), *Conceptual Structures: Logical, Linguistic, and Computational Issues (LNAI 1867)*: 55-81. Berlin, Germany: Springer-Verlag.
Spencer, J. W. 2000. Knowledge Flows in the Global Innovation System: Do U.S. Firms Share More Scientific Knowledge Than Their Japanese Rivals? *Journal of International Business Studies*, 31(3): 521-530.
Spender, J.-C. 1994. Knowing, Managing and Learning: A Dynamic Managerial Epistemology. *Management Learning*, 25(3): 387-412.
Spender, J.-C. 1996a. Making Knowledge the Basis of a Dynamic Theory of the Firm. *Strategic Management Journal*, 17(Special Issue): 45-62.
Spender, J.-C. 1996b. Organizational Knowledge, Learning and Memory: Three Concepts in Search of a Theory. *Journal of Organizational Change Management*, 9(1): 63-78.
Spender, J.-C. 1998. Pluralist Epistemology and the Knowledge-Based Theory of the Firm. *Organization*, 5(2): 233-256.
Spink, A. 1997. Study of Interactive Feedback During Mediated Information Retrieval. *Journal of the American Society for Information Science*, 48(5): 382-394.
Spink, A. 2002. A User-Centered Approach to Evaluating Human Interaction with Web Search Engines: An Exploratory Study. *Information Processing & Management*, 38: 401-426.
Spradley, J. P. 1979. *The Ethnographic Interview*. New York, etc.: Holt, Rinehart and Whinston.
Spradley, J. P. 1980. *Participant Observation*. New York, etc.: Harcourt Brace Jovanovich College Publishers.
Stamper, R. 1973. *Information in Business and Administrative Systems*. New York: John Wiley & Sons.
Stein, E. W. 1995. Organizational Memory: Review of Concepts and Recommendations for Management. *International Journal of Information Management*, 15(1): 17-32.
Stein, E. W., & Zwass, V. 1995. Actualizing Organizational Memory with Information Systems. *Information Systems Research*, 6(2): 85-117.
Stenmark, D. 2001. *The Relationship Between Information and Knowledge*. Paper presented at the IRIS 24, Ulvik, Norway.
Strauss, A. L., & Corbin, J. 1990. *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. Newbury Park, California: Sage Publications.
Stuckenschmidt, H., & Van Harmelen, F. 2005. *Information Sharing on the Semantic Web*. Berlin, etc.: Springer.
Stuurstraat, N., & Tolman, F. 1999. A Product Modeling Approach to Building Knowledge Integration. *Automation in Construction*, 8(3): 269-275.
Szulanski, G. 1996. Exploring Internal Stickiness: Impediments to the Transfer of Best Practice Within the Firm. *Strategic Management Journal*, 17(Winter): 27-43.
Szulanski, G. 2000. The Process of Knowledge Transfer: A Diachronic Analysis of Stickiness. *Organizational Behavior and Human Decision Processes*, 82(1): 9-27.

Takeishi, A. 2002. Knowledge Partitioning in the Interfirm Division of Labor: The Case of Automotive Product Development. *Organization Science*, 13(3): 321-338.

Tauber, E. M. 1985. The Gap in Gap Analysis. *Journal of Advertising Research*, 25(4): 7.

Taylor, R. S. 1968. Question-Negotiation and Information Seeking in Libraries. *College and Research Libraries*, 29: 178-194.

Te'eni, D. 2001. Review: A Cognitive-Affective Model of Organizational Communication for Designing IT. *MIS Quarterly*, 25(2): 251-312.

Te'eni, D., & Feldman, R. 2001. Performance and Satisfaction in Adaptive Websites: An Experiment on Searches Within a Task-Adapted Website. *Journal of the Association for Information Systems*, 2(3): 1-30.

Teece, D. J. 1998. Capturing Value from Knowledge Assets: The New Economy, Markets for Know-How, and Intangible Assets. *California Management Review*, 40(3): 55-79.

Thomas, J. B., Clark, S. M., & Gioia, D. A. 1993. Strategic Sensemaking and Organizational Performance: Linkages among Scanning, Interpretation, Action, and Outcomes. *Academy of Management Journal*, 36(2): 239-270.

Thompson, R., & Croft, B. 1989. Support for Browsing in an Intelligent Text Retrieval System. *International Journal of Man-Machine Studies*, 30: 639-668.

Thorngate, W. 1976. "In General" vs. "It Depends": Some Comments of the Gergen-Schlenker Debate. *Personality and Social Psychology Bulletin*, 2: 404-410.

Tolkien, J. R. R. 1995. *The Lord of the Rings*. London: HarperCollinsPublishers.

Tsang, E. W. 2002. Acquiring Knowledge by Foreign Partners from International Joint Ventures in a Transition Economy: Learning-by-Doing and Learning Myopia. *Strategic Management Journal*, 23: 835-854.

Tushman, M. L. 1977. Special Boundary Roles in the Innovation Process. *Administrative Science Quarterly*, 22(4): 587-605.

Tushman, M. L., & Nadler, D. A. 1978. Information Processing as an Integrating Concept in Organizational Design. *Academy of Management Review*, 3(3): 613-624.

Tyre, M. J., & Von Hippel, E. 1997. The Situated Nature of Adaptive Learning in Organizations. *Organization Science*, 8(1): 71-83.

Uit Beijerse, R. P. 2000. Knowledge Management in Small and Medium-Sized Companies: Knowledge Management for Entrepreneurs. *Journal of Knowledge Management*, 4(2): 162-179.

Urquhart, C. 2000. Strategies for Conversation and Systems in Requirements Gathering: A Qualitative View of Analyst-Client Communication. *The Qualitative Report*, 4(1/2).

Urquhart, C., Light, A., Thomas, R., Barker, A., Yeoman, A., Cooper, J., Armstrong, C., Fenton, R., Lonsdale, R., & Spink, S. 2003. Critical Incident Technique and Explicitation Interviewing in Studies of Information Behavior. *Library & Information Science Research*, 25: 63-88.

Van Aken, J. E. 2004. Management Research Based on the Paradigm of the Design Sciences: The Quest for Field-Tested and Grounded Technological Rules. *Journal of Management Studies*, 41(2): 219-246.

Van Baalen, P., Bloemhof-Ruwaard, J., & Van Heck, E. 2005. Knowledge Sharing in an Emerging Network of Practice: The Role of a Knowledge Portal. *European Management Journal*, 23(3): 300-314.

Van Osselaer, S. M. J., & Alba, J. W. 2000. Consumer Learning and Brand Equity. *Journal of Consumer Research*, 27(June): 1-16.

Vandenbosch, B., & Huff, S. L. 1997. Searching and Scanning: How Executives Obtain Information from Executive Information Systems. *MIS Quarterly*, 21(1): 81-107.

Varela, F. G., Maturana, H. R., & Uribe, R. 1974. Autopoiesis: The Organization of Living Systems, its Characterization and a Model. *BioSystems*, 5: 187-196.

Verschuren, P., & Doorewaard, H. 1999. *Designing a Research Project*. Utrecht: LEMMA.

Visser, M. 2004. Deutero-Learning in Organizations: A Review and a Reformulation, *Working paper series on research in relationship management, RRM-2004-07-MGT*. Nijmegen: University of Nijmegen.

Von Bertalanffy, L. 1950. The Theory of Open Systems in Physics and Biology. *Science*, 111(2872): 23-29.

Von Hippel, E. 1988. *The Sources of Innovation*. New York, Oxford: Oxford University Press.

Vosniadou, S., & Ortony, A. (Eds.). 1989. *Similarity and Analogical Reasoning*. Cambridge: Cambridge University Press.

Vossen, R. W. 1998. Relative Strengths and Weaknesses of Small Firms in Innovation. *International Small Business Journal*, 16(3): 88-94.
Walls, J. G., Widmeyer, G. R., & El Sawy, O. A. 1992. Building an Information System Design Theory for Vigilant EIS. *Information Systems Research*, 3(1): 36-59.
Walsh, J. P., & Ungson, G. R. 1991. Organizational Memory. *Academy of Management Review*, 16(1): 57-91.
Walter, J. 2000. Technological Adaptation and "Learning by Cooperation." A Case Study of a Successful Onshore Technology Transfer in Tierra del Fuego. *Journal of Technology Transfer*, 25(1): 13-22.
Wanous, J. P., Reichers, A. E., & Hudy, M. J. 1997. Overall Job Satisfaction: How Good are Single-Item Measures? *Journal of Applied Psychology*, 82(2): 247-252.
Warnken, K. 1991. *The Information Brokers: How to Start and Operate Your Own Fee-Based Service*. New York: R.R. Bowker Company.
Wearne, B. C. 1989. *The Theory and Scholarship of Talcott Parsons to 1951: A Critical Commentary*. Cambridge: Cambridge University Press.
Weick, K. E. 1969. *The Social Psychology of Organizing* (1979 ed.). Reading, Massachusetts: Addison-Wesley Publishing Company.
Weick, K. E. 1989. Theory Construction as Disciplined Imagination. *Academy of Management Review*, 14(4): 516-531.
Weick, K. E. 1995. *Sensemaking in Organizations*. London, New Dehli: SAGE Publications.
Weick, K. E. 2002. Puzzles in Organizational Learning: An Exercise in Disciplined Imagination. *British Journal of Management*, 13: S7-S15.
Weick, K. E. 2005. Knowledge and Failures of Imagination, *Keynote Presentation at the Sixth European Conference on Organizational Knowledge, Learning, and Capabilities (OKLC)*. Bostion, US.
Weick, K. E., & Roberts, K. H. 1993. Collective Mind in Organizations: Heedful Interrelating on Flight Decks. *Administrative Science Quarterly*, 38(3): 357-381.
Whetten, D. A. 1989. What Constitutes a Theoretical Contribution? *Academy of Management Review*, 14(4): 490-495.
White, B., Bennett, R., & Shipsey, R. 1982. Information and the Small Manufacturing Firm. Edinburgh: Capital Planning Information Limited.
White, H. D., & McCain, K. W. 1998. Visualizing a Discipline: An Author Co-Citation Analysis of Information Science, 1972-1995. *Journal of the American Society for Information Science*, 49(4): 327-355.
Wiig, K. M., De Hoog, R., & Van der Spek, R. 1997. Supporting Knowledge Management: A Selection of Methods and Techniques. *Expert Systems with Applications*, 13(1): 15-27.
Wijnhoven, F. 1995. *Organizational Learning and Information Systems: The Case of Monitoring Information and Control Systems in Machine Bureaucratic Organizations*. University of Twente, Enschede.
Wijnhoven, F. 1998. Designing Organizational Memories: Concept and Method. *Journal of Organizational Computing and Electronic Commerce*, 8(1): 29-56.
Wijnhoven, F. 1999a. Development Scenarios for Organizational Memory Information Systems. *Journal of Management Information Systems*, 16(1): 121-146.
Wijnhoven, F. 1999b. *Managing Dynamic Organizational Memories: Instruments for Knowledge Management*. Enschede: Twente University Press.
Wijnhoven, F. 2001. Acquiring Organizational Learning Norms: A Contingency Approach for Understanding Deutero Learning. *Management Learning*, 32(2): 181-200.
Wijnhoven, F. 2003. Operational Knowledge Management: Identification of Knowledge Objects, Operation Methods, and Goals and Means for the Support Function. *Journal of the Operational Research Society*, 54: 194-203.
Wijnhoven, F. 2005. Operational Knowledge Management. In D. G. Schwartz (Ed.), *Encyclopedia of Knowledge Management*: Idea Group Reference.
Wijnhoven, F., & Kraaijenbrink, J. 2005. Design Theory for Digital Information Services: Product-Oriented Analysis and Design Constructs for Information Services. *Journal of the Association for Information Systems*, under review.
Wilson, T. D. 1981. On User Studies and Information Needs. *Journal of Documentation*, 37(1): 3-15.

Wilson, T. D. 1994. Information Needs and Uses: Fifty Years of Progress. In B. C. Vickery (Ed.), *Fifty Years of Information Progress: A Journal of Documentation Review*: 15-51. London: Aslib.
Wilson, T. D. 1997. Information Behaviour: An Interdisciplinary Perspective. *Information Processing & Management*, 33(4): 551-572.
Wilson, T. D. 1999. Models in Information Behaviour Research. *The Journal of Documentation*, 55(3): 249-270.
Winiwarter, W. 2005. Knowledge Management and Decision Support - Incremental Learning of Transfer Rules for Customized Machine Translation. *Lecture Notes on Computer Science*, 3392: 47-64.
Winter, S. 1987. Knowledge and Competence as Strategic Assets. In D. J. Teece (Ed.), *The Competitive Challenge: Strategies for Industrial Innovation and Renewal.* Cambridge: MA: Ballinger.
Woiceshyn, J. 2000. Technology Adoption: Organizational Learning in Oil Firms. *Organization Studies*, 21(6): 1095-1118.
Wondergem, B., Van Bommel, P., & Van der Weide, T. 1998. Cumulative Duality in Designing Information Brokers. In G. Quirchmayr, & e. al. (Eds.), *LNCS*, Vol. 1460: 125-134.
Wu, M.-M., & Liu, Y.-H. 2003. Intermediary's Information Seeking, Inquiring Minds, and Elicitation Styles. *Journal of the American Society for Information Science and Technology*, 54(12): 1117-1133.
Xie, H. I. 2002. Patterns Between Interactive Intentions and Information-Seeking Strategies. *Information Processing & Management*, 38: 55-77.
Yap, A. Y., Ngwenyama, O., & Osei-Bryson, K.-M. 2003. Leveraging Knowledge Representation, Usage, and Interpretation to Help Reengineer the Product Development Life Cycle: Visual Computing and the Tacit Dimensions of Product Development. *Computers in Industry*, 51: 89-110.
Zack, M. H. 1998. Managing Codified Knowledge. *Sloan Management Review*, 40(4): 45-57.
Zack, M. H. 1999. Developing a Knowledge Strategy. *California Management Review*, 41(3): 125-145.
Zahra, S. A., & George, G. 2002. Absorptive Capacity: A Review, Reconceptualization, and Extension. *Academy of Management Review*, 27(2): 185-203.
Zander, U., & Kogut, B. 1995. Knowledge and the Speed of the Transfer and Imitation of Organizational Capabilities: An Empirical Test. *Organization Science*, 6(1): 76-92.
Zollo, M., & Winter, S. G. 2002. Deliberate Learning and the Evolution of Dynamic Capabilities. *Organization Science*, 13(3): 339-351.

VEREENVOUDIGDE SAMENVATTING (IN DUTCH)

In dit proefschrift wordt een model van kennisintegratie (KI) ontwikkeld. KI is het proces waarmee organisaties kennis van buiten hun organisatie identificeren, verkrijgen en gebruiken. In praktijk is dit een ingewikkeld proces waarbij vele activiteiten, mensen en technologieën betrokken zijn die allemaal met elkaar te maken hebben. Omdat het een ingewikkeld proces is, is het moeilijk voor managers om er een goed overzicht over te krijgen. De beschikbare literatuur helpt hen daar ook niet zoveel bij. Deze literatuur is namelijk versnipperd zodat er ook daar geen goed overzicht is van wat er allemaal komt kijken bij KI.

Het doel van dit onderzoek is om aan de oplossing van deze problemen bij te dragen. Dit is gedaan door een *systemisch model* van KI te ontwikkelen. Dit model is een soort bril die opgezet kan worden om KI problemen die in praktijk voorkomen te vinden, te verklaren en op te lossen. Een dergelijk model toont de elementen waar KI uit bestaat (bijvoorbeeld de activiteiten en mensen die er bij betrokken zijn) en de samenhang tussen deze elementen. Het laat daarmee zien dat de afzonderlijke elementen niet los staan van elkaar, maar gezien moeten worden als onderdeel van een groter geheel (een systeem). De veelgebruikte zin die hier goed bij past is 'het geheel is meer dan de som der delen'. Een voorbeeld hiervan is een huis. Dit is meer dan een verzameling elementen zoals stenen, balken, deuren, en ramen. Juist door deze elementen op een specifieke manier met elkaar te verbinden ontstaat er een geheel dat meer is dan de som der delen: in een huis kun je wonen, maar in een stapel losse elementen niet. Op dezelfde manier is KI meer dan een losse verzameling activiteiten, mensen, en technologieën. Bijvoorbeeld, met alleen het zoeken van kennis ben je er niet. Deze kennis moet ook op één of andere manier bij een organisatie naar binnen gehaald worden, verspreid worden, en toegepast worden. Het idee achter dit proefschrift is dat je KI alleen kunt begrijpen als je naar al deze verschillende activiteiten kijkt en naar de mensen en technologieën waarmee ze uitgevoerd worden.

We hebben nu een beeld gegeven van wat het betekent om KI als een systeem te beschouwen. We hebben echter nog niets gezegd over hoe het model dat is ontwikkeld in dit proefschrift er uit ziet. Dit model is betrekkelijk ingewikkeld. Als je beseft dat een dergelijk model probeert een heleboel elementen van KI weer te geven en de relaties hiertussen, dan is dit niet zo vreemd. Het model kan een beetje vergeleken worden met de bouwtekening van een huis. Een dergelijke tekening geeft een beeld van de elementen en de structuur van een huis. Hetzelfde doet een systemisch KI model: het geeft een bouwtekening van KI door aan te geven uit welke elementen een KI systeem bestaat, wat de grenzen zijn van een KI systeem en hoe de interne structuur van een KI systeem eruit ziet. Het voert te ver om hier precies uit te leggen hoe het model met deze drie zaken omgaat. Hiervoor verwijs ik naar Sectie 6.2.4 in het proefschrift.

Met de bouwtekening van KI zijn we er echter niet. Een huis is een statisch geheel. Echter, KI is een proces. Dit betekent dat er zich bepaald gedrag voordoet in het KI systeem. Als een systemisch KI model een goede weergave wil zijn van KI in praktijk, dan zal het dus ook dit gedrag moeten kunnen modelleren. Dit wordt gedaan door een onderscheid te maken tussen enerzijds patronen van activiteiten en anderzijds uitwisselingen. Patronen van activiteiten zijn groepjes van activiteiten die regelmatig in samenhang uitgevoerd worden. Bij uitwisselingen vindt er een ruil plaats waarin kennis geruild wordt voor andere kennis of voor iets anders, zoals geld. Ook dit is verder uitgelegd in Sectie 6.2.4.

We hebben nu gezien dat KI een bepaalde structuur heeft (de bouwtekening) en dat het uit gedrag bestaat. Ook hiermee zijn we er nog niet helemaal. Het gedrag vindt namelijk niet zomaar plaats. Nee, er liggen bepaalde doelen aan ten grondslag die nagestreefd worden. Het systemische model in dit proefschrift bevat daarom ook een onderdeel waarin de doelen van KI weergegeven worden. Daar bovenop komt nog dat KI niet altijd hetzelfde blijft in de loop van de tijd. Er is verandering, of, met andere woorden, er wordt geleerd, of het systeem evolueert. Evolutie van KI is daarmee het laatste onderdeel van het systemisch KI model. Ook dit is verder uitgelegd in Sectie 6.2.4.

Het model is niet puur door mij bedacht. In tegendeel, het is gebaseerd op een aanzienlijke hoeveelheid werk door mij en anderen. Ten eerste is er uitgebreid literatuur onderzoek gedaan. Zoals uit de literatuurlijst blijkt, is er veel literatuur verzameld. In Hoofdstuk 2 is geprobeerd de bevindingen van het literatuuronderzoek gestructureerd weer te geven. Daarnaast is er gebruik gemaakt van een heleboel gegevens uit de praktijk. Zo zijn in het begin van het project 33 interviews gedaan en is er een enquête uitgezet onder ruim 1700 middelgrote en kleine bedrijven in Nederland, Duitsland, Spanje, en Israël. Hiervan zijn er 317 volledig ingevuld terugontvangen. In Hoofdstuk 3 staat weergegeven hoe met al deze gegevens is omgegaan en wat het resultaat is geweest van de uitgevoerde analyses.

Met de verzamelde literatuur en de gegevens uit de interviews en de enquête is vervolgens een eerste versie van het model ontwikkeld. Hierbij is nog meer literatuur verzameld, in het bijzonder literatuur over systeemtheorie. Deze extra literatuur was nodig om gestructureerd te werk te kunnen gaan bij het ontwikkelen van het model. Er was een grote hoeveelheid materiaal verzameld en er moest een manier gevonden worden om hieruit één model te ontwikkelen. Aangezien het om een systemisch model gaat, was systeemtheorie hierbij een voor de hand liggende keuze. Hoofdstuk 4 geeft weer hoe hierbij te werk is gegaan.

Ten slotte is het in Hoofdstuk 4 ontwikkelde model getoetst in de praktijk. Het doel van deze toetsing was vooral om het model verder te verbeteren. Dit is gedaan door 17 diepte-interviews te houden met mensen uit de praktijk. In deze interviews werd respondenten gevraagd om specifieke voorbeelden van KI zo gedetailleerd mogelijk te beschrijven. Uiteindelijk zijn op deze manier 65 voorbeelden verzameld. Vervolgens zijn deze voorbeelden met het model vergeleken om te kijken of het model misschien vereenvoudigd kon worden en of het model nuttig zou kunnen zijn bij het oplossen van KI problemen in de praktijk. Dit is weergegeven in Hoofdstuk 5. Deze vergelijking heeft geleid tot een paar kleine aanpassingen van het model en tot een specificatie van het nut van het model in de praktijk.

Appendices

- I: Knowledge Functions in the KI Literature
- II: System Functions in the KI Literature
- III: Expert Group
- IV: Interview Scheme Exploratory Interviews
- V: Guidelines for Pretesting
- VI: Characterization of SMEs and the 4SF Model
- VII: Critical Incident Interview Scheme
- VIII: The System on the Cover

APPENDIX I: KNOWLEDGE FUNCTIONS IN THE KI LITERATURE

Classifications of Knowledge Functions

Author	Knowledge functions
(Akgün, Lynn, & Byrne, 2003)	Eight features of organizational learning: information acquisition, information implementation, information dissemination, unlearning, thinking, intelligence, improvisation, sensemaking, emotions, memory
(Alavi & Leidner, 2001)	Four sets of socially enacted knowledge processes: creation, storage/retrieval, transfer, application
(Allen, 1977)	Three aspects of information processing in technology: inputs (verbally encoded information), processing, and output (physically encoded and verbally encoded information)
(Bates, 1979)	29 Information search tactics grouped in four categories: monitoring tactics, file structure tactics, search formulation tactics, and term tactics
(Belkin & Croft, 1992)	Four information retrieval/filtering activities: representation, comparison, evaluation, modification
(Blecker & Neumann, 2000)	Five phases of interorganizational knowledge management in long-term virtual organizations: intention, identification, modification, organization, (inter-)action
(Boari & Lipparini, 1999)	Two interorganizational learning paths that combine knowledge creation and knowledge transfer
(Boisot, 1998)	Six phases of a learning cycle: scanning, problem-solving, abstraction, diffusion, absorption, impacting
(Carlile & Rebentisch, 2003)	Three stages of a knowledge transformation cycle: storage, retrieval, transformation
(Choo, Detlor, & Turnbull, 2000)	Three dynamics of organizational knowledge: creation, diffusion, utilization
(Choo, 2002)	Seven processes for information management: needs, acquisition, organization and storage, products and services, distribution, use, adaptive behavior
(Cohen & Levinthal, 1990)	Three abilities constituting absorptive capacity: valuing, assimilation, applying
(Corner, Kinicki, & Keats, 1994)	Five information processing processes: attention, encoding, storage/retrieval, decision, and action
(Crossan, Lane, & White, 1999)	Four learning/renewal processes through three levels: intuiting (individual level), interpreting (individual level), integrating (group level), institutionalizing (organizational level)
(Daft & Weick, 1984)	Three stages of learning processes: scanning, interpretation, learning
(Ellis & Haugan, 1997)	Eight information seeking patterns: surveying, chaining, monitoring, browsing, distinguishing, filtering, extracting, ending
(Flanagan, 1954)	Five steps for critical incident interviews: Set the stage, plan and specify, collect data, analyze data, interpret and report.
(Foster, 2004)	Three processes of non-linear information-seeking: Opening (breadth exploration, eclecticism, networking, keyword searching, browsing, monitoring, chaining, serendipity), orientation (problem definition, picture building, reviewing, identify keywords, identifying shape of existing research), consolidation (knowing enough, refining, sifting, incorporation, verifying, finishing).
(Glaser & Strauss, 1967; Strauss & Corbin, 1990)	Nine research activities in grounded theory: choosing a problem, stating research question, sample selection, data collection, data coding, data abstraction, data integration, delimiting theory, writing the theory
(Gold, Malhotra, & Segars, 2001)	Four broad dimensions of KM process capability: acquisition, conversion, application, protection
(Grant, 1996)	Two mechanisms of knowledge integration: direction, routinization
(Hansen, 1999)	Two elements of knowledge sharing: search and transfer
(Hargadon, 1998)	Four activities underlying knowledge broker innovation: access, learning, linking, and implementation
(Hedlund, 1994)	Nine knowledge transfer and transformation processes: assimilation, appropriation, extension, internalization, reflection, dialogue, expansion, articulation, dissemination
(Hickey & Davis, 2004)	Five types of activities in the requirements process: elicitation, analysis, triage, specification, verification
(Huber, 1991)	Four processes of organizational learning: knowledge acquisition, information distribution, information interpretation, and organizational memory
(Kolb, 1976)	Learning as a four-stage cycle of: concrete experience, observations and reflections, formation of abstract concepts and generalizations, testing implications of concepts in new situations
(Krikelas, 1983)	Three information behaviors: information gathering, information giving, choice
(Kulthau, 1991)	Six stages in the information search process: initiation, selection, exploration, formulation, collection, presentation
(Levine, 2001)	Five phases of software development life cycle: initiating, diagnosing, establishing, acting, learning
(Loucopoulos & Karakostas, 1995)	Nine requirements engineering activities: business analysis, context analysis, requirements acquisition, requirements identification, requirements determination, requirements analysis,

Author	Knowledge functions
	software requirements analysis, problem definition
(Majchrzak, Cooper, & Neece, 2004)	Four stages of a knowledge reuse process: reconceptualization, decision to search, search and evaluate (scanning, brief evaluations, in-depth analysis), full development
(March & Smith, 1995)	Four research activities: build, evaluate, theorize, justify
(Markus, 2001)	Five stages for knowledge reuse: capturing or documenting, packaging, distributing or disseminating, reusing
(Meyer & Zack, 1996)	Five information processing stages: acquisition, refinement, storage/retrieval, distribution, and presentation.
(Milton et al., 1999)	Five KM activities that should be supported by 'knowledge technology': personalization, codification, discovery, creation, capture
(Moorman, 1995).	Four types of information processes: information acquisition, information transmission, conceptual utilization, and instrumental utilization
(Muller & Zenker, 2001)	Three knowledge processes in knowledge transfer: codification, acquisition, interaction
(Nissen, Kamel, & Sengupta, 2000)	Six KM phases: Create, organize, formalize, distribute, apply, evolve
(Pentland, 1995)	Five knowledge processes of organizations as knowledge systems: constructing, organizing, storing, distributing, and applying.
(Pirolli & Card, 1999)	Three approaches in information foraging: information seeking, gathering, and consumption
(Preece, 2000)	Three services a knowledge-fusion system should provide: knowledge location services, knowledge transformation services, knowledge fusion services
(Scharl, Gebauer, & Bauer, 2001)	Four stages of a IS development cycle: analysis, design, implementation, usage
(Schwabe, 1999)	Eight knowledge management challenges: knowledge generation, knowledge distribution and sharing, knowledge usage, knowledge storage in organizational memory, activating organizational memory, information retrieval from organizational memory, reusing the retrieved information, updating organizational memory.
(Schwartz, Divitini, & Brasethvik, 2000)	Three tenets of internet-based knowledge management: acquire (gather, inquire, verify/validate, encode), organize (profiling, association, ranking, classification), distribute (awareness, identification, delivery)
(Shannon & Weaver, 1949)	Two communication mechanism: encoding, decoding
(Spender, 1996a)	Three knowledge processes: create, transfer, use
(Spink, 1997)	Five nested elements of an information retrieval interaction process: search strategy, consisting of cycles, consisting of interactive feedback loops, consisting of search tactics, consisting of user judgments
(Stein & Zwass, 1995)	Five mnemonic functions of organizational memory information systems: acquisition, retention, maintenance, search, retrieval
(Szulanski, 2000)	Four stages of a knowledge transfer process: initiation, implementation, ramp-up, integration
(Te'eni & Feldman, 2001)	Five cognitive processes for the location of text: goal formation, category selection, information extraction, integration, control
(Uit Beijerse, 2000)	Nine knowledge streams in KM: determine the knowledge necessary, determine the knowledge available, determine the knowledge gap, knowledge development, knowledge acquisition, knowledge lock, knowledge sharing, knowledge utilization, knowledge evaluation
(Verschuren & Doorewaard, 1999)	Seven categories of activities in research design: research objective, research framework, research issue, definition of concepts, research material, research strategy, research planning
(Walsh & Ungson, 1991)	Three organizational memory processes: acquisition, retention, retrieval
(Weick, 1989)	Three processes of theory building: variation, selection, and retention
(Wijnhoven & Kraaijenbrink, 2005)	Four information service processes: ordering, content logistics and transformation, use facilitation, transaction process.
(Wijnhoven, 1999b)	Five topics in the current memory management literature: memory creation (need detection, development, maintenance, unlearning), memory storage, memory (re)use, memory sharing, memory logistics
(Wilson, 1981; Wilson, 1994)	Four information processes: information seeking, information exchange, information transfer, information use
(Woiceshyn, 2000)	Four processes of organizational learning: observing, interpreting, integrating, acting
(Xie, 2002)	Eight information seeking methods: scanning, searching, tracking, selecting, comparing, acquiring, consulting, trial and error
(Xie, 2002)	Eight information seeking intentions: identifying, learning, finding, accessing, locating, evaluating, keeping, obtaining
(Yap, Ngwenyama, & Osei-Bryson, 2003)	Six types of knowledge processes: inspiration to create knowledge, knowledge formation, knowledge creation, knowledge representation and sharing, knowledge extension and integration, knowledge in action
(Zahra & George, 2002)	Four capabilities constituting absorptive capacity: acquisition, assimilation, transformation, exploitation

Knowledge Identification Activities

Initiator: 'R' stands for intrusive recipient; 'S' for intrusive source; and 'N' for neither.

KI activity	Initiator	Source	Field
Accessing	RS	(Hargadon, 1998)	Innovation studies
Advertising	S	(Dirksen & Kroeger, 1960)	Marketing
Alerting	S	(Broun, 2004)	Information science
Analogical reasoning	R	(Gregan-Paxton & John, 1997)	Marketing
		(Vosniadou & Ortony, 1989)	Cognitive science
Assessment	R	(Faran, Hauptman, & Raban, 2005)	Knowledge management
Association	RN	(Kraatz, 1998)	Organizational learning
Attention, drawing	S	(Davenport & Völpel, 2001)	Knowledge management
		(Robinson, 1995)	Linguistics
Boundary spanning	R	(Tushman, 1977)	Environmental scanning
		(Rosenkopf & Nerkar, 2001)	Environmental scanning
Brainstorming	RS	(Osborn, 1953)	Problem solving
Brokering	S	(Hargadon & Sutton, 1997)	Innovation studies
Browsing	R	(Borgman et al., 1995)	Information science
		(Marchionini, 1995)	Information science
Chaining	R	(Ellis & Haugan, 1997: 396)	Information science
Detection	RS	(Faran, Hauptman, & Raban, 2005)	Knowledge management
Discovery	N	(Proper & Bruza, 1999: 738).	Information brokering
		(Wondergem, Van Bommel, & Van der Weide, 1998)	Computer science
		(Adriaans, 1996)	Data mining
Distinguishing	R	(Ellis & Haugan, 1997: 399)	Information science
Encountering	S	(Erdelez, 1999: 25).	Information science
		(Rosenbloom & Wolek, 1967)	Technology transfer
Exploration	R	(Kulthau, 1991: 366)	Information science
		(Holmqvist, 2004)	Organizational learning
		(March, 1991)	Organizational learning
Filtering	S	(Ellis & Haugan, 1997: 399)	Information science
		(Belkin & Croft, 1992)	Information retrieval
Finding	N	(Ross, 1999)	Information science
Foraging	RS	(Cronin & Hert, 1995)	Information science
		(Pirolli & Card, 1999)	Psychology
Formulation	R	(Kulthau, 1991: 367)	Information science
Gap analysis	R	(Dervin, 1992)	Information science
		(Tauber, 1985)	Marketing
Gathering	R	(Urquhart, 2000)	Research methodology
Identification of needs	R	(Choo, 2002: 24)	Environmental scanning
		(Kraaijenbrink, 2003)	Knowledge brokering
Identification of source	R	(Pham & Johar, 1997)	Marketing
Initiation	R	(Kulthau, 1991: 366)	Information science
Inquiring	R	(Wu & Liu, 2003)	Information science
Intelligence	RS	(Gilad & Gilad, 1988)	Business intelligence
Interpretation	RS	(Daft & Weick, 1984)	Environmental scanning
Linking	R	(Hargadon, 1998)	Innovation studies
Localization	R	(Almeida & Kogut, 1999)	Regional networks
Mining	R	(Adriaans, 1996)	Data mining
		(Shaw et al., 2001)	Decision support systems
Monitoring	R	(Ellis & Haugan, 1997: 396)	Information science
		(Pham & Johar, 1997)	Marketing
Navigating	R	(Thompson & Croft, 1989)	Human-computer interaction
Noticing	N	(Robinson, 1995)	Linguistics
		(Huber, 1991)	Organizational learning
Presentation, directed	S	(Aguilar, 1967: 99).	Environmental scanning
Pushing	S	(Choo, 2002: 184)	Environmental scanning
Querying	R	(Hertzum & Frøkjær, 1996)	Information science
Recognition	R	(Rosenbloom & Wolek, 1967)	Technology transfer
	R	(Gray, 2001)	Knowledge management
Retrieval	R	(Belkin & Croft, 1992)	Information retrieval
		(Stein, 1995)	Organizational memory

KI activity	Initiator	Source	Field
Scanning	RS	(Marchionini, 1995: 111)	Information science
		(Keegan, 1974)	Environmental scanning
Searching	R	(Choo, 2002: 84)	Environmental scanning
		(Stein, 1995)	Organizational memory
		(Aguilar, 1967: 21).	Environmental scanning
Seeking	R	(Marchionini, 1995: 5)	Information science
		(Case, 2002: 5)	Information science
		(Kulthau, 1991)	Information science
Selection	R	(Kulthau, 1991: 366)	Information science
		(Gershoff, Broniarczyk, & West, 2001)	Marketing
Sensemaking	R	(Weick, 1989; Weick, 1995).	Sensemaking
Sourcing	R	(Gray & Meister, 2004)	Knowledge Management
Spamming	S	(Hinde, 2000)	Computer security
Surveying	R	(Ellis & Haugan, 1997: 395)	Information science
Tapping	RS	(Anand, Glick, & Manz, 2002)	Strategic management
Viewing	RS	(Choo, 2002: 84)	Environmental scanning
		(Aguilar, 1967: 21).	Environmental scanning
Zapping	R	(Heeter & Greenberg, 1985: 15).	Marketing
		(Perse, 1990)	Communication

Knowledge Acquisition Activities

Carrier: 'H' stands for human actor; 'A' for activities; 'I' for information technologies; and 'N' for non-information technologies.

KI activity	Type	Source	Field
Abduction	HAI	(Marchionini, 1995)	Information science
		(Peirce et al., 1931-)	Philosophy of science
Absorption	HAIN	(Cohen & Levinthal, 1990; Zahra & George, 2002)	Innovation studies
Accumulation	I	(Knott, Bryce, & Posen, 2003)	Resource-based view
Acquisition	IN	(Albino, Garavelli, & Schiuma, 1999: 55)	Technology transfer
		(Walsh & Ungson, 1991)	Organizational memory
		(Cooke, 1994)	Human-computer interaction
		(Gaines, 2003)	Cognitive psychology
Action research	HA	(Argyris, Putnam, & McLain Smith, 1985)	Research methodology
Adoption	N	(Woiceshyn, 2000)	Organizational learning
		(McCardle, 1985)	Technology adoption
Analysis	HAI	(Cooke, 1994)	Human-computer interaction
Appropriation	I	(Teece, 1998)	Knowledge management
Asking	H	(Davis, 1982)	Information systems
Assimilation	HAIN	(Hedlund, 1994: 76)	Knowledge management
Brokering	H	(Hargadon & Fanelli, 2002; Hargadon & Sutton, 1997)	Innovation studies
Collaboration	HA	(Powell, Koput, & Smith-Doerr, 1996)	Innovation studies
		(Inkpen, 1996)	Knowledge management
Collection	I	(Kulthau, 1991: 368)	Information science
Communication	HI	(Daft & Lengel, 1984)	Organization theory
		(Te'eni, 2001)	Information systems
Cooperation	HA	(Walter, 2000)	Technology transfer
		(Loebbecke & Van Fenema, 2000)	Knowledge management
Course, following	HI	(Devon & Bush, 1996)	Technology transfer
Deduction	I	(Marchionini, 1995)	Information science
		(Peirce et al., 1931-)	Philosophy of science
Discussion	HI	(Cooke, 1994)	Human-computer interaction
Dissemination	HAI	(Hedlund, 1994: 76)	Knowledge management
Elicitation	HI	(Cooke, 1994)	Human-computer interaction
		(Hickey & Davis, 2004)	Information systems
Experimentation	HAIN	(Davis, 1982)	Information systems
		(Cook & Campbell, 1979)	Research methodology
Explicitation	I	(Urquhart et al., 2003)	Research methodology
Extraction	I	(Ellis & Haugan, 1997)	Information science
		(Faran, Hauptman, & Raban, 2005)	Knowledge management
Grafting	H	(Huber, 1991)	Organizational learning
Hiring	H	(Dyer & Nobeoka, 2000; Song, Almeida, & Wu, 2003)	Knowledge management
Imitation	AN	(Zander & Kogut, 1995)	Knowledge management
Import	I	(Hedlund, 1994: 76)	Knowledge management
Incorporation	I	(Jin & Sendhoff, 1999)	Artificial intelligence
Induction	HAI	(Marchionini, 1995)	Information science
		(Peirce et al., 1931-)	Philosophy of science
Inferencing	HI	(Ross Jr. & Creyer, 1992)	Marketing
		(King, Keohane, & Verba, 1994)	Research methodology
Insourcing	N	(Hirschheim & Lacity, 2000)	Information systems
Interaction	HA	(Ellis et al., 2002)	Information science
Interviewing	H	(Cooke, 1994)	Human-computer interaction
		(Kahn & Cannell, 1957)	Research methodology
Learning	HI	(Huber, 1991)	Organizational learning
	I	(Van Osselaer & Alba, 2000)	Marketing
	A	(Kolb, 1984)	Learning
	HI	(Gioia & Manz, 1985)	Organizational learning
	HAN	(Anzai & Simon, 1979)	Psychology
	HAN	(Epple, Argote, & Devadas, 1991)	Knowledge management
Logistics	I	(Wijnhoven, 2005)	Knowledge management

KI activity	Type	Source	Field
Mobility	H	(Almeida & Kogut, 1999)	Regional networks
		(Song, Almeida, & Wu, 2003)	Knowledge management
Moving	H	(Tyre & Von Hippel, 1997)	Knowledge management
Negotiation	H	(Taylor, 1968)	Information science
		(Grünbacher et al., 2004)	Information systems
Observation	HA	(Spradley, 1980)	Research methodology
		(Cooke, 1994)	Human-computer interaction
Outsourcing	N	(Takeishi, 2002)	Theory of the firm
	N	(McKay & Marshall, 2000: 212)	Knowledge management
	N	(Oates, 1998)	Virtual organizations
Participation	HAN	(Spradley, 1980)	Research methodology
		(Cooke, 1994)	Human-computer interaction
Prompting	HI	(Browne & Rogich, 2001)	Information systems
Protection	I	(Gold, Malhotra, & Segars, 2001)	Knowledge management
Replication	N	(Nelson & Winter, 1982)	Economics
	N	(Rivkin, 2001)	Knowledge management
Reporting	I	(Cooke, 1994)	Human-computer interaction
Reverse engineering	N	(Argote, 1999)	Knowledge management
Sourcing	I	(Gray & Meister, 2004)	Knowledge management
		(Howells, James, & Malik, 2003).	R&D management
Teaching	HAI	(Devon & Bush, 1996)	Technology transfer
Technology transfer	AIN	(Bessant & Rush, 1995: 97)	Technology transfer
		(Autio, 1994)	Technology transfer
Transfer	HAIN	(Argote, 1999: 151).	Knowledge transfer
		(Alavi & Leidner, 2001)	Knowledge management

Knowledge Utilization Activities

Type: 'L' stands for logistics; 'T' for transformation; 'A' for application.

KI activity	Type	Source	Field
Abstraction	T	(Boisot, 1995: 49)	Knowledge management
Adaptation	T	(Argyris & Schön, 1978)	Organizational learning
		(Kraatz, 1998)	Organizational learning
Application	A	(Alavi & Leidner, 2001)	Knowledge management
		(Gold, Malhotra, & Segars, 2001)	Knowledge management
		(Alavi & Tiwana, 2002: 1030)	Information science
		(Pentland, 1995: 3)	Information systems
Appropriation	LT	(Hedlund, 1994: 77)	Knowledge management
Articulation	T	(Hedlund, 1994: 76)	Knowledge management
Assimilation	TA	(Albino, Garavelli, & Schiuma, 1999: 55).	Technology transfer
Codification	T	(Ericsson & Simon, 1998),	Research methodology
		(Zollo & Winter, 2002)	Organizational learning
		(Boisot, 1995: 42)	Knowledge management
Combination	T	(Kogut & Zander, 1992)	Knowledge management
		(Nonaka, 1994: 19)	Knowledge management
		(Wiig, De Hoog, & Van der Spek, 1997)	Knowledge management
Communication	L	(Albino, Garavelli, & Schiuma, 1999: 55).	Technology transfer
		(Putnam, Phillips, & Chapman, 1996)	Organization studies
Conservation	L	(Levitt & March, 1988)	Organizational learning
Consolidation	L	(Wiig, De Hoog, & Van der Spek, 1997)	Knowledge management
Construction	T	(Pentland, 1995: 3)	Information systems
Conversion	T	(Gold, Malhotra, & Segars, 2001)	Knowledge management
Creation	T	(Alavi & Tiwana, 2002: 1029)	Information science
		(Alavi & Leidner, 2001)	Knowledge management
Decontextualizing	T	(Ackerman & Halverson, 2000)	Organizational memory
		(Markus, 2001)	Knowledge management
Developing	T	(Wiig, De Hoog, & Van der Spek, 1997)	Knowledge management
Dialogue	LT	(Hedlund, 1994: 77)	Knowledge management
Diffusion	L	(Galunic & Rodan, 1998: 1198)	Resource based view
		(Boisot, 1995: 52);	Knowledge management
Direction	LT	(Grant, 1996: 379)	Knowledge management
Dispersion	L	(Galunic & Rodan, 1998: 1198)	Resource based view
Dissemination	L	(Wijnhoven, 2003)	Knowledge management
Distribution	L	(Choo, 2002)	Environmental scanning
		(Wiig, De Hoog, & Van der Spek, 1997)	Knowledge management
Embedding	LT	(Faran, Hauptman, & Raban, 2005)	Knowledge management
Exploitation	A	(Braganza, Edwards, & Lambert, 1999)	Knowledge management
		(Holmqvist, 2004)	Organizational learning
Extension	LT	(Hedlund, 1994: 77)	Knowledge management
Externalization	T	(Nonaka, 1994: 19)	Knowledge management
Formalization	T	(Nissen, Kamel, & Sengupta, 2000)	Knowledge management
Implementation	A	(Hargadon, 1998)	Innovation studies
		(Akgün, Lynn, & Byrne, 2003)	Organizational learning
Indexing	LT	(Anderson & Pérez-Carballo, 2001: 233)	Information science
Institutionalizing	T	(Crossan, Lane, & White, 1999)	Organizational learning
Integration	T	(Huang, Newell, & Pan, 2001: 161)	Knowledge management
		(Alavi & Tiwana, 2002: 1030)	Information science
		(Paton, Goble, & Bechhofer, 2000)	Artificial intelligence
Intelligence	T	(Akgün, Lynn, & Byrne, 2003)	Organizational learning
Internalization	T	(Nonaka, 1994: 19)	Knowledge management
		(Hedlund, 1994: 76-77)	Knowledge management
Interrelating	T	(Weick & Roberts, 1993: 374)	Sensemaking
Organization	TL	(Pentland, 1995: 3)	Information systems
Presentation	LT	(Kulthau, 1991: 368)	Information science
Processing	LT	(Galbraith, 1974)	Organization theory
		(Tushman & Nadler, 1978)	Organization theory
		(Levin, Huneke, & Jasper, 2000)	Decision sciences

KI activity	Type	Source	Field
Recombination	AT	(Galunic & Rodan, 1998; Schumpeter, 1934)	Resource based view
Recontextualizing	T	(Ackerman & Halverson, 2000)	Organizational memory
Recording	L	(Levitt & March, 1988)	Organizational learning
Reflection		(Hedlund, 1994: 77)	Knowledge management
Retaining	L	(Argote, 1999)	Organizational learning
Retention	LT	(Stein, 1995; Walsh & Ungson, 1991)	Organizational memory
		(Weick, 1969: 125)	Social psychology
		(Argote, McEvily, & Reagans, 2003: 572)	Knowledge management
Reuse	A	(Garud & Nayyar, 1994; Markus, 2001)	Knowledge management
		(Majchrzak, Cooper, & Neece, 2004)	Knowledge management
Routinization	TA	(Grant, 1996: 379)	Knowledge management
		(March & Simon, 1958)	Organization theory
Sharing	L	(Hansen, 2002; Postrel, 2002)	Knowledge management
		(Jarvenpaa & Staples, 2000)	Information systems
Socialization	TL	(Nonaka, 1994: 19)	Knowledge management
Storage	L	(Stein, 1995; Stein & Zwass, 1995; Walsh & Ungson, 1991; Wijnhoven, 1999b)	Organizational memory
Transformation	T	(Wijnhoven, 2003; Wijnhoven, 2005)	Knowledge management
Translation	T	(Winiwarter, 2005)	Computer science
		(Frenkel, 2005)	Management and politics
Transmission	L	(Moorman, 1995)	Marketing
Unlearning	T	(Hedberg, 1981)	Knowledge management
Use	A	(Byström & Järvelin, 1995; Dervin, 1992)	Information science
		(Hayek, 1945)	Economics
Utilization	A	(Burnett, Brookes-Rooney, & Keogh, 2002)	Knowledge management
		(John & Martin, 1984: 173)	Marketing
		(Patton, 1978: 50)	Evaluation research
		(Duncan, 1972)	Technology transfer

APPENDIX II: SYSTEM FUNCTIONS IN THE KI LITERATURE

Author	Activities
(Binney, 2001)	Six elements of the KM spectrum: transactional KM, analytical KM, asset management KM, process-based KM, developmental KM, innovation/creation KM
(Braganza, Edwards, & Lambert, 1999)	Four types of knowledge projects that contribute to innovation: exploration, exploitation, expedition, enhancing
(Cooper, 2001)	Five stage-gates for product development: preliminary analysis, business case, development, pilot, and launch and implementation
(Daft & Lengel, 1986)	Two roles of information processing: reducing uncertainty and reducing equivocality
(Galbraith, 1974)	Two strategies for information processing: reducing the need (by creation of slack resources and creation of self-contained tasks) and increase the capacity (by investments in vertical information systems and creation of lateral relations)
(Geurts & Roosendaal, 2001)	Four functions to fulfilled in the publishing process: registration, archiving, certification, and creating awareness
(Gray, 2001)	Four knowledge management practices for problem solving: encouraging serendipity (for recognition of new problems), knowledge creation (for solving new problems), knowledge acquisition (for solving re-occurring problems), and raising awareness (for recognition of re-occurring problems)
(March & Smith, 1995)	Four types of research outputs: constructs, models, methods, and instantiations
(March, 1991)	Two aspects of organizational learning: exploration and exploitation
(McKeown & Leitch, 1993)	Four functions of information systems: supporting decision making, supporting reporting, supporting transaction processing, and adding value to goods and services
(Moorman, 1995)	Four cultures emphasizing particular information processes: hierarchy (internal orientation, formal governance), market (external orientation, formal governance), adhocracy (external orientation, informal governance, and clan culture (internal orientation, informal governance)
(Pahl & Beitz, 1996)	Four stages of engineering design: planning and clarifying the task, conceptual design, embodiment design, and detailed design
(Remus & Schub, 2003)	Four types of knowledge processes: application in knowledge intensive business processes, knowledge value adding processes, KM processes, and knowledge flows
(Santoro & Gopalakrishnan, 2000)	Four cultural traits of knowledge transfer activities: adaptability, sense-of-mission, involvement, consistency
(Stein & Zwass, 1995)	Four functions of organizational memory information systems concerning organizational effectiveness: goal attainment, adaptation, integration, pattern maintenance
(Stenmark, 2001)	Four functions of intranets: creating an information space, an awareness space, a communication space, and a collaboration space
(Tushman, 1977)	Two roles of boundary spanners: connecting to external systems and connecting the internal system
(Tushman, 1977)	Three innovation phases: idea generation, problem solving, and implementation
(Vandenbosch & Huff, 1997)	Focused search for organizational efficiency, scanning for organizational efficiency and effectiveness
(Wilson, 1999)	Four stages of problem solving in which information seeking should reduce uncertainty: problem identification, problem definition, problem resolution, solution statement

APPENDIX III: EXPERT GROUP

In this study, an expert group consisting of researchers and practitioners was consulted at the following moments:

1. Development of the interview scheme for the exploratory interviews
2. Conducting the exploratory interviews
3. Discussing results and conclusions of the exploratory interviews
4. Development of the questionnaire for the exploratory study
5. Pretesting and improving the questionnaire
6. Conducting the data collection of the questionnaire
7. Discussing results and conclusions of the questionnaire

The expert group consisted of the following persons:

Researchers:

1. Professor Hans-Horst Schröder - RWTH Aachen
2. Dr. Antonie Jetter - RWTH Aachen
3. Dr. Hannah Zaunmüller - RWTH Aachen
4. Dipl.-Kff. Dina Franzen - RWTH Aachen
5. Dr. Aharon Hauptman - ICTAF Tel Aviv
6. Dr. Yoel Raban - ICTAF Tel Aviv
7. Dr. Fons Wijnhoven - University of Twente
8. Dr. Aard Groen - University of Twente

Consultants:

1. Doron Faran MA - NetKnowledge
2. Antonio Lázaro - Socintec (Grupo Azertia)
3. Charo Elorrieta - Socintec (Grupo Azertia)
4. Juan Pedro Lopez - Socintec (Grupo Azertia)

High-Tech SMEs:

1. Ralf Schapdick - Aixtron
2. Joachim Hergeth - Aixtron
3. Johannes Kreuser - Cerobear
4. Boris Rautenberg - Cerobear
5. Reinhard Scholz - HEAD Acoustics
6. Michael Euskirchen - HEAD Acoustics
7. Lior Agassy - Optibase

APPENDIX IV: SCHEME FOR THE EXPLORATORY INTERVIEWS

I'd like to ask you questions about following topics:

- The way product development is done in your organization
- The main part: the way you usually integrate this knowledge in your company and barriers you face during that process, for different stages in the product development process and different domains of knowledge.
- The value of a portal we plan to develop
- Policy related questions

The following data will only be used for our administration and to classify your company. The interview is strictly confidential and anonymity is guaranteed in every report.

Name	M/F	Name interviewer
Position in company		Date of interview
Company		Duration interview
Branch of industry/products		Atmosphere (interested? Is KI important?)
Year of establishment		
Offices in (countries)		
Number of employees		
Number of employees on R&D		
R&D division?	Yes/No	
Estimated turnover/year		

Characterization of KI in NPD

1. How would you describe the usual development of new or improved products in your company? *(Formalized/informal? Structured/unstructured? Initiated by marketing/R&D/...? Mainly new products or improved? When/why/how is it started? Pro-active or reactive? etc.)*

We distinguish between 3 main activities in the NPD process: generation of ideas/options, selection of projects, and execution of NPD (the actual development). Moreover we distinguish between 3 domains of knowledge that we think are relevant: market, technological, and organizational knowledge.

2. Could you please indicate for each phase and knowledge domain what external sources your company uses?
(None, employees, customers, suppliers, competitors, government, universities, conferences, consultants, magazines, databases etc.. Why are they important?)

	Market knowledge	Technological knowl.	Organizational knowl.
Generating NPD ideas and options			
Selecting NPD projects			
Executing NPD projects			

For each filled cell, you will ask questions about identification, acquisition and utilization (questions 3-5). When most cells are filled (when company uses external knowledge for almost everything), ask which are most important or problematic according to interviewee.

We distinguish between 3 stages of the process of getting knowledge from external sources: identification, acquisition and utilization. For each of the cells in the table from question 2 these stages exist. I'd like to ask questions about how you do this, what tools, methods and techniques you use and what problems/barriers you face.

For each cell on the next three pages for which the respondent indicated he/she uses external knowledge, you can use these questions to fill in the cell. When the respondent only speaks about methods, ask him also about tools and techniques, and vice versa. The last page of this document (TMTs) can be used to trigger the respondent.

Identification

3a. How do you identify this external knowledge?

Methods: procedures, steps, how do they do it: by an existing relation, Internet, conferences, trade shows, knowledge brokers, Active search or passive? How is the KI-process triggered? Search for needs or opportunities?

Tools & techniques: what do they use? IT/non-IT

(Make a list of TMTs you use, IT/non-IT, Search tools, yellow pages, mapping, benchmarking, TMTs for knowing what to look for, etc. etc.)

3b. Is this identification successful?

(Do you know what you need? Do you find what you need? Is it within the budget and time? What problems or barriers do you face? How did you solve problems? Did the TMTs function well? Why not? Why didn't you use TMTs? How can it be improved?)

Acquisition

4a. How do you get this knowledge to your organization?

Methods: procedures, steps, how do they do it? (Buy it, cooperate, education, hiring people, communities of practice, reverse engineering, etc.)

Tools & techniques: what do they use? IT/non-IT: (Make a list of TMTs, IT/non-IT, for communication, for cooperation, for documentation, related to IPR, for project management, decision-making, etc. etc.)

4b. Is this acquisition successful?

(Do you get what you need? Is it within budget and time? Is the process problematic, or the transfer of ownership? What problems or barriers do you face? How did you solve problems? Did the TMTs function well? Why not? Why didn't you use TMTs? How can it be improved?)

Utilization

5a. How do you get this knowledge spread and used in your organization?

Methods: procedures, steps, how do they do it (Formal or informal meetings, store in documents, store in IT, document management, content management, mentors/tutors, etc.)

Tools & techniques: what do they use? IT/non-IT (Make a list of TMTs, IT/non-IT, for communication, for cooperation, for documentation, for storage, for project management, decision making, etc. etc.)

5b. Is this utilization successful?

(Does the knowledge reach the right persons? Is it within budget and time? Can it be used? Is it used? What problems/barriers do you face? How did you solve problems? Did the TMTs function well? Why not? Why didn't you use TMTs? How can it be improved?)

The following table was included three times: for each NPD stage (generating NPD options, selecting NPD options, and realization)

	Market knowledge	Technological knowledge	Organizational knowledge
Identification	How + TMTs	How + TMTs	How + TMTs
	Problems/barriers	Problems/barriers	Problems/barriers
Acquisition	How + TMTs	How + TMTs	How + TMTs
	Problems/barriers	Problems/barriers	Problems/barriers
Utilization	How + TMTs	How + TMTs	How + TMTs
	Problems/barriers	Problems/barriers	Problems/barriers

Portal

We plan to develop a portal on which information will be accessible about TMTs and experiences with them. On this portal you will be able to pose your problem with getting external knowledge and it will match this with a TMT that is suitable for that problem. I'd like to ask you a few questions about this portal.

6. Would this portal be valuable to you?

(Under what conditions? Wherefore would you use it? What would it be a substitute for or a complement? What could be its most valuable contribution?)

7. What should it be like?

(What functionality? What information should be on it? Who do you see as an expert on KI? What conditions should be fulfilled? Is privacy, security, anonymity important?)

8. Would you be willing to pay for the portal?

(In what form? Money or other values (like submitting tips)? How much? Subscription, pay per use, etc.? Should tool suppliers pay, or consultants, or advertisers?)

Policy related questions

9. Which governmental measures do you know that foster the acquisition of knowledge from external sources by SMEs?

(Funding for e.g. market surveys, patents, technology forecasts, funding for consultancy, subsidizing employment of knowledge manager,)

10. Which problems or barriers can or should government diminish?

(In identification, acquisition, transfer, ...)

11. What could government do to improve your identification, acquisition or utilization of external knowledge?

(legislation, subsidies, websites, free consultancy, facilities)

Finally

12. Do you have any additional comments or questions? Did I forget something important?

Additional information and the results of this study will be published on www.kinx-europe.com.
Thank you for you cooperation. Can we ask you again for cooperation further in the project?

APPENDIX V: GUIDELINES FOR PRETESTING

Number of SMEs

2-3 SMEs or more in every country, which are not our industry partners (they know about the subject, so pretesting results won't be reliable)

Setting

It is preferable to do a round table talk in which all SMEs discuss together the questionnaire. If this in not possible on a short term, individual pretesting is an option as well.

Procedure

- Tell the SMEs that every comment or question they have is valuable and important to us
- Give them the questionnaire, ask them to fill it out and ask them to think aloud and say everything that comes to their mind whilst they are filling it out.
- Observe and write down if you see them hesitating, spending a lot of time on a question, etc.

Example questions that we want to be answered

- How long did it take them to fill out the questionnaire?
- Which questions were difficult to answer?
- What questions are missing?
- What questions are superfluous?
- What answering categories need to be revised?
- Should we add answering options? (e.g. when they fill in the 'other, please specify' category)
- What formulations need to be revised?
- Do the questions ask what we think they ask?

In order to answer the questions it might be not enough to let the SMEs think aloud. It can be necessary to ask them questions like

- How did you interpret a question?
- Can you repeat this in your own words?
- How would you formulate this question?
- How did your choose your answer?
- Why did you choose this answer?
- Was this question clear to you?
- Was it easy for you to keep in mind a particular situation?

Reporting

Please write down every problem, suggestion, comment, etc. they make our you observe

Your own comments

In addition I'd like to hear your own comments on the questionnaire. If you make a comment, please be very detailed and make a concrete suggestion how to improve the questionnaire. (please make a very clear distinction between your comments and the comments of the respondents!)

APPENDIX VI: CHARACTERIZATION OF FOUR SF MODEL

Interpretation: 22.9 in the cell 'Germany – passive search' means that 22.9 % of the SMEs scoring low on passive search is German. Hence, from the SMEs scoring high on passive search, 20.4 % is German. In the table, * means: significant at .05 level.

	Passive search			Goal attainment			Cooperation			Integration		
	Low	*High*	*Sig.*	*Low*	*High*	*Sig.*	*Low*	*High*	*Sig.*	*Low*	*High*	*Sig.*
Country	**179**	**93**		**136**	**142**		**153**	**119**		**126**	**144**	
Germany	22.9	20.4	.680	27.2	16.9	.067	26.8	14.3	.027*	24.6	19.4	.366
Israel	34.6	24.7	.166	26.5	36.6	.133	30.7	32.8	.765	30.2	34.0	.576
Netherlands	30.2	45.2	.048*	38.2	31.7	.356	33.3	38.7	.466	34.1	36.1	.784
Spain	12.3	9.7	.545	8.1	14.8	.100	9.2	14.3	.213	11.1	10.4	.862
Size	**168**	**89**		**126**	**136**		**144**	**113**		**119**	**137**	
2-9	14.9	13.5	.779	16.7	12.5	.376	14.6	14.2	.929	20.2	8.8	.015*
10-24	15.5	14.6	.865	19.8	12.5	.138	18.1	12.4	.253	10.1	21.2	.027*
25-49	12.5	10.1	.594	12.7	11.0	.695	13.9	8.8	.241	12.6	10.9	.699
50-99	16.7	22.5	.306	17.5	19.1	.754	20.1	15.9	.433	21.8	16.1	.286
100-199	22.6	22.5	.981	16.7	27.2	.070	19.4	26.5	.234	17.6	26.3	.144
>200	17.9	16.9	.855	16.7	17.6	.848	13.9	22.1	.117	17.6	16.8	.869
Age	**162**	**88**		**122**	**132**		**137**	**112**		**113**	**135**	
Before 1965	13.6	19.3	.273	13.9	16.7	.579	18.2	12.5	.254	13.3	17.8	.373
1966-1980	11.7	18.2	.193	15.6	12.1	.459	15.3	11.6	.429	18.6	10.4	.086
1981-1990	20.4	22.7	.699	22.1	20.5	.772	23.4	18.8	.433	24.8	17.8	.230
1991-1995	17.3	14.8	.640	17.2	15.2	.683	13.9	19.6	.264	15.9	16.3	.943
1996-1998	19.1	10.2	.093	14.8	17.4	.597	14.6	17.9	.523	15.9	16.3	.943
1999-2001	17.9	14.8	.564	16.4	18.2	.732	14.6	19.6	.335	11.5	21.5	.057
Industry	**173**	**92**		**130**	**139**		**148**	**116**		**122**	**141**	
24 Chemicals	9.8	12.0	.612	10.8	10.1	.859	11.5	8.6	.470	9.8	10.6	.840
29 Machinery	27.2	39.1	.098	40.0	23.0	.013*	31.1	31.9	.907	33.6	29.8	.582
30 Office machinery	13.3	6.5	.113	10.0	12.9	.476	12.8	9.5	.422	13.1	8.5	.254
31 Electrical machinery	5.8	2.2	.189	2.3	6.5	.106	4.1	5.2	.672	4.1	5.0	.743
32 Radio, TV, etc.	23.1	15.2	.175	18.5	22.3	.486	18.9	21.6	.636	18.0	22.7	.405
33 Medical instrum.	12.7	14.1	.763	12.3	13.7	.757	13.5	12.9	.897	13.1	13.5	.936
34 Motor vehicles	5.2	6.5	.667	4.6	6.5	.519	5.4	6.0	.831	4.1	7.1	.311
35 Other transport	2.9	4.3	.540	1.5	5.0	.117	2.7	4.3	.483	4.1	2.8	.581
% sales new products	**177**	**90**		**133**	**139**		**150**	**116**		**125**	**140**	
0 %	.6	1.1	.626	.8	.7	.975	1.3	-	-	1.6	-	-
1-20 %	21.5	31.1	.134	29.3	19.4	.098	27.3	21.6	.348	28.8	21.4	.230
21-40 %	25.4	30.0	.496	28.6	25.2	.589	24.7	29.3	.467	27.2	25.0	.726
41-60 %	13.6	12.2	.775	9.8	16.5	.125	10.7	15.5	.273	12.8	12.9	.990
61-80 %	13.0	12.2	.867	14.3	10.8	.415	12.7	12.9	.952	9.6	15.0	.214
81-100 %	19.8	11.1	.103	14.3	20.9	.197	17.3	17.2	.986	12.8	22.9	.055
Unknown	6.2	2.2	.162	3.0	6.5	.191	6.0	3.4	.351	7.2	2.9	.111
Main product	**172**	**90**		**129**	**138**		**148**	**115**		**123**	**138**	
Machinery/equipment	37.2	42.2	.537	42.6	35.5	.351	41.2	35.7	.472	40.7	38.4	.773
Components	27.3	22.2	.438	24.8	26.1	.836	23.0	29.6	.297	26.8	24.6	.727
Consumer products	9.9	12.2	.582	14.0	7.2	.091	14.2	6.1	.046*	9.8	11.6	.651
Materials	12.2	12.2	.998	10.9	13.0	.605	9.5	14.8	.212	11.4	12.3	.827
Software	8.1	4.4	.279	3.9	10.9	.037*	6.8	7.8	.749	8.1	6.5	.631
Other	5.2	6.7	.645	3.9	7.2	.246	5.4	6.1	.818	3.3	6.5	.237
Production process	**176**	**90**		**131**	**139**		**150**	**115**		**123**	**141**	
Single unit	22.2	26.7	.475	25.2	23.0	.717	27.3	18.3	.130	28.5	19.1	.120
Small series	42.0	45.6	.680	45.8	41.0	.550	44.0	43.5	.949	43.9	42.6	.868
Large series	21.0	14.4	.242	16.0	20.9	.356	17.3	20.0	.617	17.1	20.6	.515
Mass production	9.1	8.9	.959	9.9	7.9	.580	8.0	10.4	.514	5.7	12.1	.087
Unknown	5.7	4.4	.677	3.1	7.2	.135	3.3	7.8	.115	4.9	5.7	.779
% R&D employees	**162**	**85**		**119**	**133**		**137**	**110**		**111**	**135**	
5 % or less	29.6	30.6	.896	33.6	25.6	.239	32.8	26.4	.355	32.4	27.4	.472
5-10 %	15.4	29.4	.020*	21.8	18.0	.499	19.7	20.9	.835	22.5	18.5	.488
10-40 %	29.0	20.0	.186	23.5	28.6	.435	22.6	29.1	.317	23.4	12.7	.614
40 % or more	25.9	20.0	.365	21.0	27.8	.276	24.8	23.6	.852	21.6	27.4	.364
% Academic degree	**165**	**87**		**124**	**132**		**143**	**108**		**116**	**135**	
0-20 %	46.1	58.6	.182	58.1	42.4	.077	54.5	44.4	.263	52.6	48.9	.681
21-40 %	16.4	6.9	.048*	9.7	15.9	.165	10.5	16.7	.181	8.6	17.0	.067
41-60 %	12.1	8.0	.347	11.3	10.6	.869	10.5	11.1	.882	12.1	8.9	.435
61-80 %	12.1	14.9	.556	11.3	15.2	.397	12.6	13.9	.778	14.7	11.9	.541
81-100 %	13.3	11.5	.697	9.7	15.9	.165	11.9	13.9	.660	12.1	13.3	.780

APPENDIX VII: CRITICAL INCIDENT INTERVIEW SCHEME

General

Name interviewer	Duration interview
Date + time interview	Atmosphere (interested? Importance of subject?)

Company	**Personal**
Company name	Name M/F
Industry /products	Position in company
Year of establishment	Age / years in company / years in this position
Located in (countries)	Education / year
Number of employees	Work-related Internet experience / # years Beginner 1 2 3 4 5 Expert / ....
Number on R&D / R&D Budget	Explanation
Separate R&D department? Yes/no	
Estimated sales and profit / year	Uses Internet .....times/.....hour a month/week/day
% sales from new products	Number of patents
Innovation character (AWT classification): leader / developing / technology following	

Characterize your company, in particular recent developments
(what is produced, for whom, what does the product look like, what are recent developments, current considerations, future plans)

Describe the NPD process in your company → **Exhibit page 1**
(formal/informal, structured/unstructured, initiated by marketing/R&D, particularly new or improved products, cutting edge or followers)

What is your role in this? What do you do? What does your average day look like?
(manager, engineer, developer, researcher, controller)

Describe the role of external information in this process, what is the general purpose of this information?
(for your company, for NPD and for your own job, in which phases is it important, for what, how important, why, what information)

Critical incident descriptive questions → **Exhibit page 2-6 (afterwards)**
Think of a recent case in which you very successfully *(and unsuccessfully)* searched outside your company for information for product development *(successful means useful information)*

Wait until you see a recognition/confirmation
Describe this case as detailed as possible in chronological order
Take note of all sources that are mentioned

a. Situation: When was it? What was the problem/task/situation in which you needed it? Which product? Which NPD phase?
b. Information: What information did you want? What criteria should it fulfill? What did you know yourself already and what not? How important is it to have this information?
c. Sources: Where did you start searching? How did you know you had to start there, how did you find out? What did you expect to find? Where did you look after that?
d. Results: What did you find at the end? Are you satisfied with it? Does it resemble what you thought you needed? What problems did you face?

Explanatory questions: Please indicate why you searched in the way you searched
For every source: ask for the reason → **Exhibit page 7**

a. External search: Why searched for information and not in another way? Why external and not internal?
b. Sources: Why this source? Why not another source? What did you expect to find here?
c. Internet: Why Internet? Why this website? Why not another website? How did you know this? (heard, read, experienced, expected)

Normative/reflective questions

You have now provided a detailed report on how it went. Now I'd like to know how you wished it went

Which problems did you face? Went everything as was hoped for? What would an ideal case look like? What should have gone differently? What could be improved? What would an ideal website be like?
Do you use this site regularly? How 'normal' is this case? What is so special about it? Why could you remember it?
Repeat this for unsuccessful example

General questions

Next to these specific questions I still have a few more general questions:
In which situations do you use Internet and in which situations don't you use Internet?
What would you like to use Internet for, what not?
Which websites are good according to you and which are bad, why?

For the continuation of this study, I'd like to ask you the following:

Interested in a group discussion? What should it look like? With whom? More persons in your company?

Exhibit page 1: NPD-phases

1. idea generation, idea selection, idea realization
2. **(Rogers, 1983):** Needs/problems, Research (fundamental and applied), Development, Commercialization, Diffusion and adoption, Consequences
3. **(Pahl & Beitz, 1996):** Planning and clarification of task, Conceptual design (function), Embodiment design (form), Detailed design
4. **(Cooper, 2001):** Preliminary analysis, Business case, Development, Pilot, Launch and implementation
5. your own phases

Exhibit page 2: Characteristics of the situation (MacMullin & Taylor, 1984)

The situation in which the information is needed, can be characterized as follows:

Information need	Type of situation			Information need
Small, detailed sets of data	**Discovery**	0 0 0 0 0 0 0 0 0 0	**Design**	Options, alternatives, ranges
Probabilistic data on how to proceed	**Ill-structured**	0 0 0 0 0 0 0 0 0 0	**Well-structured**	Hard, quantitative data
Ways to simplify the problem	**Complex**	0 0 0 0 0 0 0 0 0 0	**Simple**	Path to goal state
Preferences and directions	**Amorphous goals**	0 0 0 0 0 0 0 0 0 0	**Specific goals**	Goal operationalization and measurement
Soft, qualitative data to define initial state	**Initial state not understood**	0 0 0 0 0 0 0 0 0 0	**Initial state understood**	Clarify unclear aspects of initial state
Views of the world definition of terms	**Assumptions not agreed upon**	0 0 0 0 0 0 0 0 0 0	**Assumptions agreed upon**	Information to help define problems
Information to make assumptions explicit	**Assumptions not explicit**	0 0 0 0 0 0 0 0 0 0	**Assumptions explicit**	Range of options, frameworks to analyze problems
Substantive and future oriented information	**New pattern**	0 0 0 0 0 0 0 0 0 0	**Familiar pattern**	Procedural and historical information
Best available information	**Magnitude of risk great**	0 0 0 0 0 0 0 0 0 0	**Magnitude of risk not great**	Cost-effective search
Opinions of experts, forecasts, scenarios	**Not susceptible to empirical analysis**	0 0 0 0 0 0 0 0 0 0	**Susceptible to empirical analysis**	Objective, aggregated data
Information about external environment	**External imposition**	0 0 0 0 0 0 0 0 0 0	**Internal imposition**	Clarification of internal goals, objectives

Exhibit page 3: Goals for the use of knowledge (Taylor, 1984)

I need the information in order to…

…**make sense:** to make sense of a situation or context
(e.g. Are there similar situations? What does this company do in addition?)
…**to understand the problem:** more specific, to get a better understanding of a problem
(e.g. What does a particular problem consist of? What is the cause of the problem?)
…**to know how to do something:** instrumental, to know what and how to do something
(e.g. Instructions, procedures)
…**to know the facts:** to describe an object or event
(e.g. exact numbers, measurements)
…**to confirm something:** to verify other information
(e.g.. Second opinion, checks)
…**to project:** to forecast what will happen in the future
(e.g. forecasts, expectations, estimations)
…**to motivate others:** to motivate people to do something, to involve them
(e.g. explaining the seriousness of a situation, to convince others)
…**personal reasons**: to develop and achieve relations, status, and personal goals
(e.g., to control something, to safeguard ones position)

Exhibit page 4: Information traits (MacMullin & Taylor, 1984)

The information that I thought I needed and that I found can be characterized as follows:

Needed	QUANTITY CONTINUUM	Found
0 0	**Quantitative** *(numbers, specific, overall picture)*	0 0
0 0	**Qualitative** *(reasons, assumptions, nuances, details)*	0 0
	DATA CONTINUUM	
0 0	**Hard data** *(proven in practice)*	0 0
0 0	**Soft data** *(no proof, only assumptions)*	0 0
	TEMPORAL CONTINUUM	
0 0	**Past** *(what was)*	0 0
0 0	**Present** *(what is)*	0 0
0 0	**Future** *(what will be)*	0 0
0 0	**Prescriptive** *(what ought to be)*	0 0
	SOLUTION CONTINUUM	
0 0	**Single solution** *(one best solution)*	0 0
0 0	**Range of solutions** *(alternatives)*	0 0
	FOCUS CONTINUUM	
0 0	**Precision** *(for well-defined situation)*	0 0
0 0	**Diffusion** *(broader, for a less well-defined situation)*	0 0
	SPECIFICITY OF USE CONTINUUM	
0 0	**Applied** *(directly applicable, situation specific)*	0 0
0 0	**Theoretical** *(more general, abstract, broader applicable)*	0 0
	SUBSTANTIVE CONTINUUM	
0 0	**Procedural** *(directly applicable, how to do something)*	0 0
0 0	**Descriptive** *(description of objects, what is something composed of)*	0 0
	AGGREGATION CONTINUUM	
0 0	**Single case** *(case, sample, example)*	0 0
0 0	**Completeness** *(complete information, population)*	0 0
	CAUSAL/DIAGNOSTIC CONTINUUM	
0 0	**Diagnostic** *(what is happening)*	0 0
0 0	**Causal** *(why is it happening)*	0 0

Exhibit page 5: information in new product development (Faulkner & Senker, 1995)

The information I need can be classified as follows:

About	1	2	Category	Examples
Natural world			Scientific and engineering theory	*'laws' of nature, theoretical tools*
			Properties of materials	*Properties of natural and artificial materials*
Design practice			Design criteria and specifications	*Understanding of user requirements* *Demands of company and technology* *Specification of components*
			Design concepts	*Fundamental operating principles* *Normal configurations* *Creative ideas*
			Design instrumentalities	*Judgment skills, ways of doing and thinking*
			Design competence	*General design competence* *Competence in specific product area*
			Practical experience	*Best practices*
Experimental R&D			Experimental/test procedures	*Product testing procedures*
			Research instrumentalities	*Ability to use experimental techniques and equipment* *Ability to interpret test and experimental results*
			Research competence	*General research competence* *Competence in particular specialism*
			Experimental and test data	*Results of testing procedures*
Final product			New product ideas	*New product/market combinations*
			Operating performance	*Performance of components or materials* *Pilot production, field trials, etc.* *User experience*
			Production competencies	*Design requirements for manufacture* *Competence in pilot production / scale up*
Environment			Market information	*Trends, needs and demands of market segments*
			Socio-economic knowledge	*Economic climate, cultural factors*
			Governmental knowledge	*Legislation, political situation, policy changes*
			Supportive processes	*Finance, management, organizational processes*
Knowledge			Knowledge of knowledge	*Location of information* *Availability of tools, materials, services*

Exhibit page 6: types of sources

External sources: customers, suppliers, other companies than customers of suppliers, advisor, research institute, university, branch organization, innovation centre, conference, brochures, catalogues, magazine, book, newspaper, database, internet, other, ...

Internal sources : Colleagues (staff, production, R&D, direction), own archive, internal library, database, intranet, other, ...

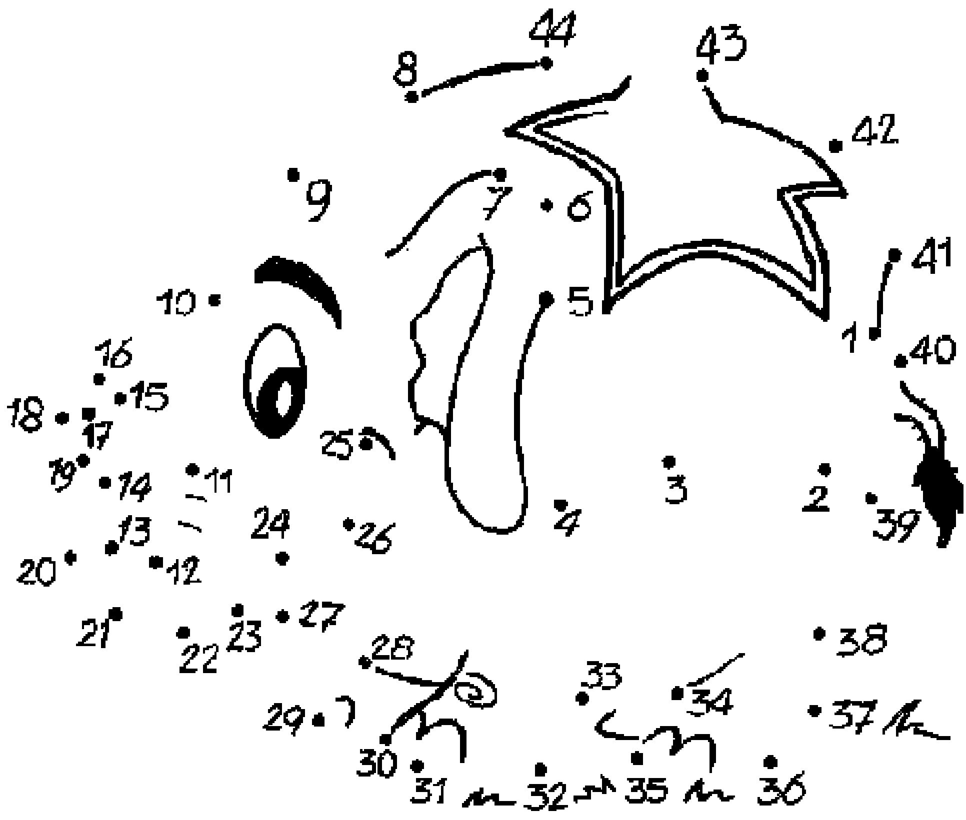
Exhibit page 7: Considerations for source selection

The following reasons have guided me in the selection of particular sources:

Least effort Easy to get information from I had to be there anyway Costs me least effort **Speed** Is very fast Everything can be found at one spot **Availability** Only option, virtually no alternatives Others have no access **Acquaintance** I know what to expect I know I can find it there **Cost / benefit ratio** Brings most compared to alternatives Best cost/benefit ratio Is cheap **Suitability** Information from this source is relevant Information from this source is up-to-date Information from this source is useful **Quality** Information is of good quality Information is correct/reliable **Quantity** You get a lot of information there You only get what you want You don't' get any superfluous information **Applicability** Information is directly applicable Information is in my language / jargon Customizable to my preferences **Diversity** Considers things from a different perspective Puts different emphasizes than I do Has a broad range of information **Similarity** Approaches problems in the same way as I do Thinks in a similar way Specifically addresses my subject **Gratification** Is gratifying Is fun to do Nice way to present information	**Awarenes/ Interpretation** Makes me better aware of the situation Becomes clear what I really need Makes me better understand the situation **Learning** I learn a lot there You can always ask more There is personal supervision Makes me search better **Self-confidence** Makes me less insecure Gives me faith to proceed I know how to handle it **Trust** It is trustworthy Privacy is assured Does not leak to others **External pressure** I am more or less obliged to use it Everybody does so We get a subsidy for it **Reputation** Is recommended by others Has a good reputation **Relations** Connects to other useful sources I have a relation with it Has good contacts with others **Influence** Than I inform the source about what I am doing I can influence the source **Comparison** Possibility of feedback Possibility to compare to others **Activity** Provides information pro-actively Keeps me informed automatically Does not push its information **Manageability** Easy to learn Easy to handle **Time perspective** Keeps track of what I've asked Does not keep track of what I've asked Probably there is more to it than I have found out **Other**

APPENDIX VIII: THE SYSTEM ON THE COVER

Perhaps you have wondered what are the dots and numbers on the cover of this thesis. I hope you have indeed missed the forest for the trees. By including only part of the dots and numbers and by not including their connections, I wanted to illustrate what it means to not have a systemic look at KI. By only looking at a few elements and by not considering their position and relationship, one cannot grasp KI, or find the elephant. Rather than including the famous poem of John Godfrey Saxe about the six blind men that failed to establish the true nature of an elephant, it seemed more effective to me to let you experience the blindness yourself.



INDEX

About the Author

Jeroen Kraaijenbrink was born on 18 February 1978 in Winterswijk, the Netherlands. He followed his secondary education at the Christelijk College Schaersvoorde in Aalten, where he received his atheneum diploma in 1996. Starting in 1996, he studied Industrial Engineering and Management at the University of Twente until he received his MSc degree in 2002. Starting in 1997, he studied Public Administration at the same university where he received his MA degree in 2001. In February 2002, he started as a doctoral student at the University of Twente at the department of Business Information Systems. His PhD project was supervised by prof.dr. Robert Stegwee, dr. Fons Wijnhoven, and dr. Aard Groen. The PhD project has resulted in the present dissertation. Jeroen's research interests include knowledge integration, innovation, systems theory, network theory, research methodology, and research philosophy. He can be contacted at j.kraaijenbrink@utwente.nl.