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Berends, J.J.

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Knowledge Sharing in Industrial Research

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Dit proefschrift is goedgekeurd door de promotoren:

prof.dr.ir. M.C.D.P. Weggeman
en
prof.dr.ir. K. Debackere

Copromotor:
dr.ir. J.D. van der Bij

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I.

INTRODUCTION

This thesis is about knowledge sharing in industrial research. The objective of this study was to gain more insight in knowledge processes in organizations and especially in the contribution of knowledge sharing to industrial research practices. For reasons discussed later, I will speak of technical communication, in stead of knowledge sharing, in large parts of the thesis. Past research has established that technical communication contributes to the performance of researchers and research groups. The information processing approach and the knowledge-based theory of the firm provide theoretical explanations for this value. The information processing approach interprets technical communication as the transfer of information, serving to reduce the uncertainty and ambiguity associated with tasks. The knowledge-based theory of the firm interprets technical communication as knowledge transfer, and knowledge transfer as one among a number of possible knowledge integration mechanisms. However, past research has not explored the different ways in which knowledge sharing contributes the practices of industrial researchers, nor the ways in which this is realized. This implies that the theoretical interpretations of the value of technical communication are not based upon a detailed examination of this process. In this study I took both an empirical and a theoretical stance in order to deal with these research problems. First, two ethnographic field studies served to explore in detail the work that is done in technical communication, its role in the practices of researchers and the way this is realized. This resulted in an outline of a theory on the contribution of technical communication to industrial research practices. Second, these findings were used to evaluate and contribute to the theoretical interpretations offered by the information processing approach and the knowledge-based theory of the firm.

This introductory chapter sets the scene for this thesis. First, I will sketch the recent upsurge of interest in knowledge and knowledge processes that inspired this study. Second, I will introduce the object of the study, knowledge sharing, and I will explain why I will speak of technical communication in the main part of this thesis. Third, I will review past studies of technical communication in industrial research. Fourth, I will discuss the information processing approach and the knowledge-based theory of the firm. Fifth, I will discuss extended insights with regard to communication in work- (and especially research-)settings. Finally, I will discuss the research problems alluded to above in more detail.

1.1. Knowledge in organizations

In the faraway past, some of the fathers and founders of the field of organization science already recognized the value of knowledge and expertise in organizations. Smith (1776) argued that one of the sources of the enormous power of the division of labor is that it provides the opportunity to increase expertise in a specialized area. Almost a century ago, Taylor (1916) wrote: "*The first of the great principles of scientific management (...) is the deliberate gathering together of the great mass of traditional knowledge which, in the past, has been in the heads of the workmen, recording it, tabulating it, reducing it in most cases to rules, laws, and in many cases to mathematical formulae (...).*" Smith and Taylor recognized knowledge as an explanatory variable and a phenomenon that should be managed. But only from the last decade on have knowledge and knowledge processes in organizations received systematic theoretical and empirical attention. During the past decade, knowledge has become a central concept in the field of organization studies. This has brought us already considerable new insight into the role of knowledge in organizations. For example, research has shown that Taylor's call for the externalization of personal knowledge in order to instruct workers with standardized procedures has serious drawbacks (Brown and Duguid 1991; Tsoukas 1996). It is not only knowledge itself that has taken a central place in the field of organization studies. The concept of knowledge also underlies other concepts like core competencies (Prahalad and Hamel 1990), organizational learning (e.g., Levitt and March 1988; Huber 1991), dynamic capabilities (e.g., Teece et al. 1997), managerial cognition (e.g., Walsh 1995), organizational memory (e.g., Walsh and Ungson 1991) distributed cognition (e.g., Hutchins 1995; Madhavan and Grover 1998), intellectual capital (e.g., Edvinsson 1997) and communities of practice (Wenger 1998).

A first question that needs to be answered is why knowledge is important for organizations and organization studies. For most organizations, knowledge does not have an intrinsic value, but an instrumental value. Most organizations do not collect knowledge for its own sake. The prime contribution of knowledge is that it enables actions. Epistemologists have considered knowledge to consist of (a subset of) true beliefs about the world. If a chemical engineer has a correct belief about the effectiveness of a catalyst, he is enabled to design a productive process. If someone has a correct belief about the cause of a particular quality problem in production, he is in a better position to solve that problem. Without such knowledge he is left in the dark. Knowledge can be compared with an accurate map of a district. This is quite a natural analogy. Beliefs are sometimes referred to as 'maps by which we steer' (Braddon-Mitchell and Jackson 1998). Giere (1999) compares scientific theories and cognitive models with maps. Having a map of the territory in which we want to travel, gives us the coordinates of the places we want to go and routes to get there. The map enables efficient travelling and avoids moving around by trial and error. In such a way, knowledge about its technology, customers, competitors and ways of organizing helps an organization to act efficiently and effectively. From this perspective, knowledge has two opposites: ignorance (the lack of a map) and error (an erroneous map). An erroneous map may lead us in the wrong directions.[1]

The value of knowledge for organizations is theoretically recognized by calling knowledge a production factor alongside with capital, labor and materials (Drucker 1993). These different resources are used alongside with each other in organizations. When going for a journey it is not enough to have a map. It may be necessary to have food, some money and a compass too. Likewise, the application of knowledge in organizational practices depends on the availability of other resources (Spender 1994). However, it is claimed in the literature that the relative importance of knowledge has increased (Nonaka and Takeuchi 1995; Drucker 1993). Of course, knowledge has always been important. This is evident from the attention paid to knowledge by Smith and Taylor. Even in jobs that are not considered knowledge intensive, knowledge plays a crucial role. For example, a bus-driver would be unable to do his job without an accurate mental map of the streets in his district. This holds for the present as well as for the past. But it is claimed in the literature that knowledge has become more and more important in the current economy and society in general. This can be attributed to two forces. In the first place, more and more members of developed countries are performing knowledge intensive work. Examples of knowledge intensive work are advocacy, surgery, consultancy and research. Fewer people work in labor dominated jobs in industry and farming. In the second place, knowledge is becoming more and more quickly outdated. Technologies develop at an increasing speed. Knowledge workers have to learn in an increasing pace to keep their knowledge up-to-date (Weggeman 1997). Economists have demonstrated empirically that the growth of technological knowledge is an important source of economic growth (Scherer 1999; Solow 1957). This makes knowledge a strategically important source of competitive advantage (Nonaka 1994; Grant 1996b; DeCarolis and Deeds 1999).

In line with the increased interest for and importance of knowledge for organizations, recently the so-called 'knowledge-based theory of the firm' (KBT) has been developed

[1] Nevertheless, even wrong maps may have their value, as is illustrated nicely by a story recounted by Weick (1987). In this story a group of Hungarian soldiers is lost in a snowstorm in the Alps. One of them appears to have a map. By interpreting the map and their surroundings they manage to return to a familiar place. However, the map actually represented the Pyrenees. But the availability of that map, be it an inadequate one, turned the soldiers' despair into decisive actions.

(Demsetz 1991; Kogut and Zander 1992; 1996; Grant 1996b; Spender 1996; Galunic and Rodan 1998; DeCarolis and Deeds 1999). This theory has both an economic and an organizational side to it. As an economic theory, it considers knowledge to be the primary factor explaining the existence and boundaries of the firm. As an organizational theory, the KBT uses knowledge and knowledge processes to explain the structure and performance of organizations. It emphasizes the collective characteristics of knowledge in organizations. Theorists of the KBT argue that the capabilities of an organization reside not only in the knowledge of individuals, but particularly in the way this knowledge is integrated (Kogut and Zander 1992; Grant 1996a; 1996b; 1997). The collective nature of these organizational capabilities makes them difficult to transfer, replicate or imitate. This is enhanced by the fact that the need for knowledge integration makes organizational knowledge idiosyncratic and situated (Brown and Duguid 1998). Furthermore, it is especially the tacit component of capabilities that makes them a source of competitive advantage (Winter 1987; Berman et al. 2002). Tacit knowledge is that knowledge that we use unconsciously when we take conscious actions or apply explicit knowledge (Polanyi 1958). Tacit knowledge is difficult to transfer, observe or sell. Capabilities built on tacit knowledge are therefore hard to replicate by others. Competitive advantage based on such collective, situated and tacit capabilities has a higher chance of being sustainable.

Some evidence for the importance of knowledge integration and tacit knowledge is presented by Berman et al. (2002). Using data from the National Basketball Association from 1980 to 1993, they found a strong positive relationship between the mean number of years players of a team had played together and the number of games won. According to these authors this is due to the fact that joint experience enables teams to learn how to play together. Berman et al. (2002) call this 'team-based tacit knowledge'. This capacity for integration is as important as the quality of individual players is. Other evidence for the importance of the integration of distributed knowledge and cognition can be found in studies of distributed cognitive systems (e.g., Hutchins 1995; Weick and Roberts 1993).

The focus of organization studies has not only been on stocks of knowledge in organizations, but also on knowledge processes in organizations. It is through processes that the value of knowledge is realized. Knowledge application, knowledge sharing and knowledge creation are most often mentioned as central knowledge processes (e.g., Moenaert and Caeldries 1996: 305; Coombs and Hull 1998; DeCarolis and Deeds 1999). The importance of knowledge application is self-evident. A map can only be of value on a journey when it is used (though it is sometimes difficult to determine which maps one will need at a journey). The application of knowledge also underlies the concept of knowledge integration (Grant 1996a; 1996b). Knowledge integration presupposes the concerted application of knowledge. The second knowledge process mentioned is knowledge sharing. According to DeCarolis and Deeds (1999) both stocks and flows of knowledge determine the success of firms. Knowledge sharing is the primary topic of this thesis. We will turn to it in the next section. The third core knowledge process is knowledge development, also called knowledge construction, knowledge generation and knowledge creation. Organizational knowledge development creation has been studied previously under the label 'organizational learning' (e.g., Argyris and Schön 1978). Knowledge development or learning widens the action-repertoire of organizations (Huber 1991). By organizational learning, organizations may increase efficiency (Epple et al. 1991), develop new technologies (Nonaka 1994), adapt to the environment (Cyert and March 1963), enact their environment (Daft and Weick 1984) and enhance chances of survival (Baum and Ingram 1998). Organizational knowledge creation is the more important when environments change, technologies develop and competitors improve, when existing knowledge becomes outdated and competitive advantages erode.

The recognition of the importance of knowledge and knowledge processes in organizations has spurred interest in knowledge management.[2] When organizations thrive on knowledge application, knowledge sharing and knowledge creation it seems wise to spend management attention to those processes. Among others, Nonaka (1991), Nonaka and Takeuchi (1995), Weggeman (1997), Davenport and Prusak (1998), Hansen et al. (1999) and Dixon (2000) have presented suggestions for the improvement of knowledge processes in organizations. Many organizations have implemented some of these suggestions. Several success-stories have been published. Nevertheless, critical studies, focusing on failures and unintended consequences, have appeared as well (e.g., Prichard et al. 2000). These critical studies show that the management of knowledge is not straightforward and may be served by an increased understanding of the processes involved.

1.2. Knowledge sharing and technical communication

This study started primarily as a study of knowledge sharing in industrial research. Knowledge sharing is one of the central knowledge processes in organizations. In a good analytical tradition, we should answer the question 'What do you mean?' after having introduced such a concept. That is a more difficult question to answer than it

[2] I will stick to the habit of using the label 'knowledge management' to refer to literature on knowledge and knowledge processes in organizations, though this literature is not confined to a management point of view.

may seem. Although the phrase knowledge sharing is central in much of the knowledge management literature, and to most people it will have some meaning, it has not been clearly delineated and defined yet. If we take a look at the use of the concept we see that it is used interchangeably or tightly connected to concepts like technical communication, knowledge transfer[3], knowledge dissemination, knowledge flow, knowledge integration, information transfer, information flow, technology transfer (Gruber and Marquis 1969), internal consulting (Allen 1977) and vicarious learning (Huber 1991). Many publications that have 'knowledge sharing' in their titles now, would probably have had 'information transfer' as a label before the rise of knowledge management. There are reasons to argue that this is indeed acceptable. Earlier literature interpreted technical communication as information transfer. Current organization science literature often equates information and explicit knowledge (e.g., Kogut and Zander 1992). Combining these two claims yields the claim that technical communication is the transfer of (explicit) knowledge. To some this may be completely acceptable. Others may be inclined to protest. It is possible that some readers have grounded beliefs about the delineations of these different concepts. Presumably, the concepts have a different emotional value. Knowledge sharing is a 'feel good' concept. Both 'knowledge' and 'sharing' have a positive emotional value. This is exemplified by the use of the term 'knowledge sharing' in several television and newspaper advertisements. Sharing is associated with openness ('sharing your feelings') and community interest. Knowledge transfer has more technical connotations. It seems to be associated with organized processes such as classroom teaching and innovation adoption. This holds a fortiori for information transfer. This concept may evoke images of computers, telephone wires and train tables. Communication seems to be the most all-embracing concept. This is underscored by Watzlavick's dictum that it is impossible not to communicate (Watzlavick et al. 1968: 72).

Having such an ill-defined term as a core concept yields difficult problems. How do we steer data-gathering activities if it is unclear what we are looking for? And what literature is relevant to the topic at hand? One strategy to overcome this problem is to give an analysis of the concept of knowledge sharing and its relations with other concepts any way. However, that option has several shortcomings. The literature does not offer the grounds for sharp distinctions. To make thorough distinctions, it is better to ground these in a minute empirical examination of the processes involved.

[3] 'Knowledge transfer' has also been used for other types of transfer than transfer by means of communication, for example by moving an employee from one department to another, or applying one piece of knowledge in a different context (e.g., Argote and Ingram 2000). When the notion 'knowledge transfer' is used in this thesis, it refers only to knowledge transfer by means of communication.

Any distinctions made beforehand would be arbitrary. In order to avoid the problems associated with using ill-defined terms, I choose another strategy. In stead of using the phrase 'knowledge sharing', I will use the phrase 'technical communication' throughout this thesis. This notion has been used before to refer to work-related communication in industrial research and development (e.g. Allen and Cohen 1969; Tushman 1978; Brown and Utterback 1985). The adjective technical is meant to distinguish it from communication about managerial issues and social communication. Because the context of this research is industrial research, I will also use the phrase research-related communication as a substitute for technical communication. The phrase 'technical communication' seems to be less theory-impregnated than knowledge sharing, knowledge transfer, information transfer, etcetera. It is relatively clear what instances should be identified as technical communication and what not (see also chapters two and three). Another advantage of technical communication above knowledge sharing, information transfer and other concepts is that, if there is a difference between them, technical communication will be the broader concept. That means that a study of technical communication enables the delineation of those other concepts. For example, if technical communication turns out to be a broader concept than knowledge transfer is, then the set of instances of technical communication contains both instances of knowledge transfer and instances that are not knowledge transfers. One of the goals of this thesis was to develop more grounded analyses of the similarities and differences between some of the concepts mentioned above.

There are several reasons why knowledge sharing and technical communication in industrial research seem to be interesting phenomena. Technical communication exemplifies the dynamic and collective nature of knowledge and knowledge processes in organizations. Communication seems to be involved in the realization of organizational capabilities. It is considered an important mechanism for knowledge integration (Grant 1996b). It is also considered a prerequisite for organizational learning (Shrivastava 1983; Huber 1991; Kim 1993). Knowledge sharing is one of the processes that many organizations should improve, according to knowledge management writers (Davenport and Prusak 1998; Dixon 2000). Above all, past research has established over and over again that technical communication contributes to the performance of industrial research.

In this thesis I will limit myself to the study of technical communication in industrial research. Industrial research is for several reasons a particularly interesting environment to do research into knowledge processes. Doing research is a knowledge intensive activity. Furthermore, it is specifically aimed at the creation of new knowledge and technological options. Finally, technical communication plays an important role in industrial research. Empirical studies have determined over and over again that the amount of technical communication is an important predictor of R&D performance and innovation success (see below).

Later in this introductory chapter I will describe in more detail the questions that were asked about technical communication in this study. In order to arrive at the research problems that this study addressed, I will first review relevant parts of the extant literature. Section 1.3 describes past research concerning technical communication in industrial research. Among others, it reports on the importance of technical communication and alludes to issues that have not yet been addressed adequately. Section 1.4 describes two theoretical interpretations of the importance of technical communication, which will be disputed in this thesis. Section 1.5 discusses extended insights in communication, which have guided the empirical part of this study.

1.3. Past research

1.3.1. Introduction

In this section I will review past research on technical communication. Since this study is primarily located within the knowledge management literature, I will turn to that field in this review. But as soon as we broaden our semantical scope from knowledge sharing and knowledge transfer to technical communication, a wide range of past research presents itself as extremely relevant as well. Whereas the notions of knowledge sharing and knowledge transfer seem to be under-researched yet, technical communication in industrial research has been a topic of scientific investigation for over fifty years (e.g., Herner 1954; Pelz and Andrews 1966; Gerstberger and Allen 1968; Allen and Cohen 1969; Nelson and Pollock 1970; Whitley and Frost 1973; Johnston and Gibbons 1975; Holland et al. 1976; Allen 1977; Tushman 1977; 1978; de Meyer 1985; Moenaert and Souder 1990; 1996; Keller 1994; Anderson et al. 2001; reviews of parts of this literature can be found in Allen 1977; Moenaert and Souder 1990; Brown and Eisenhardt 1995; Leckie et al. 1996). Most of these studies have been undertaken from research management and innovation management perspectives. They have often been allied with an information processing approach to the study of organizations (Tushman and Nadler 1978). This information processing approach can be seen as a precursor of knowledge oriented theorizing (Grandori and Kogut 2002). The information processing approach and the knowledge management literature are the two most important fields of research with which the current thesis is associated. These fields of research have most to say about technical communication within the broader landscape of management and organization science. Nevertheless there are other perspectives that are relevant as well. These are among others the sociology of science and technology (e.g., Jasanoff et al. 1995), social epistemology (e.g., Goldman 1999), cognitive anthropology (e.g., Lave and Wenger 1991; Hutchins 1995), library and information studies (e.g., Pinelli et al. 1993; Leckie et al. 1996), discourse analysis (e.g., Mey 1993) and social perspectives in cognitive psychology (e.g., Okada and Simon 1997). In the following literature review the emphasis will be on the information processing approach and the knowledge management literature, but these other perspectives will receive attention too.

1.3.2. The linear communication model

Underneath most studies of technical communication lies a linear communication model. Its terminology is used broadly and reviews of the field apply it as well (De Meyer 1985; Moenaert and Souder 1990; Szulanski 1996). Several linear communication models are developed in the past (see Rogers and Kincaid 1981). Most of them are tributary to Shannon and Weaver's (1949) model of communication (see Figure 1.1). In this model a message is sent by an information source via a communication channel to a destination. In that process the message is encoded by a transmitter into a signal, influenced by noise and decoded by a receiver into a message again. A similar model is presented by Berlo (1960). Berlo (1960: 32) lists the following elements of a communication process: a communication source; an encoder, a message; a channel; a decoder; and a communication receiver. In human communication, the same person often fulfills the role of source and encoder. The same holds for the roles of decoder and receiver. Therefore this model is sometimes referred to as the source-message-channel-receiver model (e.g., Moenaert and Souder 1990). Models like these are called linear communication models, since they model the one-way flow of a message from a source to a receiver. Following Shannon and Weaver (1949), the messages transferred have frequently been labeled information. The use of a linear communication model is often allied with the view that communication is the transfer of information (e.g., Allen 1977; Moenaert and Souder 1996).

Szulanski (2000) notes that most knowledge sharing research implicitly or explicitly uses the linear communication model as well. The use of such communication models illustrates the conceptual proximity of technical communication and knowledge transfer. Gupta and Govindarajan (2000) and Boone (1997) for example make the reliance upon a source-channel-message-receiver model explicit. The use of such a model is implicit in other writings on knowledge processes in organizations. For example, Grant (1996b: 111) states that knowledge transfer involves both transmission and receipt. Likewise, Davenport and Prusak (1998: 101) distinguish transmission and absorption as elementary components of knowledge transfer.

Hansen (1999) distinguishes two main phases of knowledge sharing: searching and transferring. Both of these phases can be subdivided again. According to him, searching encompasses 'looking for' and 'identifying' and transferring encompasses 'moving' and 'incorporating'. This last subdivision is in accordance with Grant (1996b) and Davenport and Prusak (1998).[4] Szulanski (1996; 2000) discerns four phases: initiation, implementation, ramp-up, integration. It should be noted, however, that he is primarily concerned with the transfer of best practices from one department to another. He describes these transfers as organized projects. Therefore it is questionable whether this conceptualization can be applied also to single occasions of technical communication between individuals within an organization. But it is noteworthy that both Hansen (1999) and Szulanski (1996) identify something like an initialization phase, called 'searching' by Hansen (1999). Such a phase is absent in the original linear communication models.

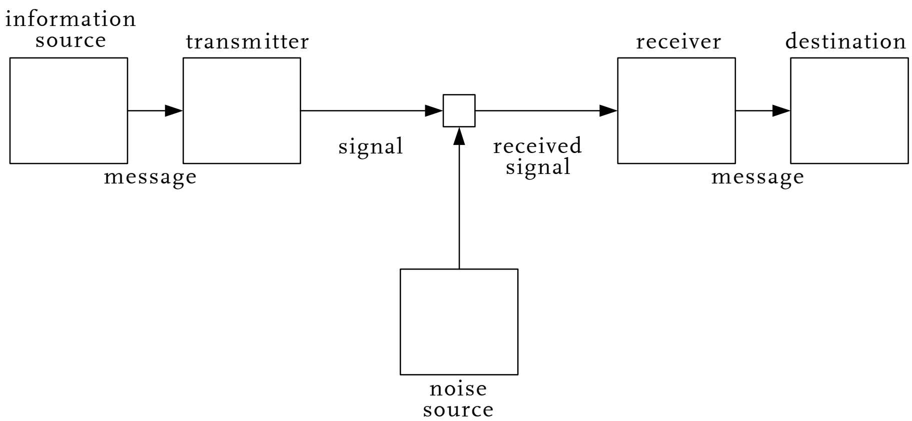

Figure 1.1: Schematic diagram of a general communication system (Shannon and Weaver 1949).

Nowadays, few researchers would consider linear communication models like these as fully satisfying models of communication. Such a model does not underlie this current study either. Several points of critique have been raised against the linear communication model and insight in communication has moved further. Nevertheless, this model still exerts influence, as is acknowledged for example by

[4] The idea that knowledge sharing includes searching whereas knowledge transfer does not, could be used to discriminate the two. Nevertheless, it seems quite arbitrary to me to make that distinction on this ground.

Szulanski (2000), and has certainly guided past research. Therefore I have presented it before the review of past research. Critiques and more recent insights are postponed to section 1.5.

1.3.3. Technical communication and performance

One major lesson that can be drawn from past research is that technical communication contributes to the performance of industrial research. Early studies have predominantly taken a descriptive stance toward the role of communication. One of the topics that has been studied extensively is the use of different sources and channels of information in R&D (this terminology reflects the influence of linear communication models). Members of R&D projects can use a variety of information sources. Gerstberger and Allen (1968) distinguish literature, vendors, customers, other external sources, project members, other R&D colleagues, in-company research reports, group discussion, experimentation and other divisions. Nowadays the internet and intranets should be added to that list. These sources can be clustered into external sources and internal sources. Sometimes a researcher's own personal experience is added as a third major source (e.g., Johnston and Gibbons 1975). Appendix 1 presents an overview of some early innovation studies that focused on the relative importance of internal, external and personal sources of information. This overview indicates that internal sources of information are quite important for industrial researchers and engineers.

The category 'internal sources' consists of several more specific sources. Therefore it is useful to take a more detailed look at the sources used. A general distinction can be made between interpersonal contact and literature. Appendix 2 reports a number of studies concerning the relative use of personal contacts versus publications. Four out of these six studies show more reliance upon personal contacts than upon printed materials. Similar results can be found if we focus on the use of particular sources and channels. Of the nine information channels distinguished by Gerstberger and Allen (1968: 275) literature is used most frequently. Other group members take up the second place and technical staff from other groups the fourth place. In a study of Chakrabarti et al. (1983) work group members are the most frequently used source amidst 22 different sources. Experts outside one's own group take up the fifth place in their investigation. The recent study of Anderson et al. (2001) shows conversation with coworkers inside the organization as the second source used, after one's personal store of technical information.

The above mentioned descriptive studies suggest that the amount of technical communication is a major explanatory variable of R&D and innovation performance. This has indeed been confirmed in many studies that have related technical communication to performance. Appendix 3 provides an overview of studies correlating communication intensity in research and development and performance. In a study of 1311 scientists and engineers from 11 organizations, Pelz and Andrews (1966) found that better performing researchers communicated more than worse performing researchers. Other studies have correlated the total amount of communication of project members and project performance. Rothwell et al. (1974) compared 43 pairs of successful and failed innovations of chemical processes and scientific instruments. Their results indicate that successful projects are to a significant degree more likely to have higher internal and external communication.[5] Later studies have discriminated between types of projects. The main conclusion that can be drawn from these studies is that different communication partners are useful for different projects. The type of R&D project (research, development or technical service) determines to a large extent what communication is useful (see Appendix 3). For research projects, external communication and intraproject communication have been found to be predominantly useful. The effect of communication with others in the laboratory has sometimes been found to have a positive effect on research projects. Communication with other organizational functions has been found to have a negative effect. In contrast to that, for development projects it is has been found to be especially useful to communicate with other parts of the organization (Katz and Tushman 1979; Allen et al. 1980). This finding has been corroborated in many later studies on the integration of organizational functions in product innovation.

These studies have also hinted at a related phenomenon, which has been explicated by Tushman and Nadler (1978): communication has a curvilinear relationship with performance. Communication is useful up to a certain point. More communication beyond that point has a detrimental effect. It has been hypothesized that this point is determined by the amount of uncertainty associated with a particular task. Keller (1994) has explicitly tested this hypothesis. Keller found that especially the match of uncertainty and information processing explains performance. I will come back to this in section 1.4. Allen (1977: 103) found another contingency factor. He showed that also the stage of a project matters. High performing projects distributed the time spent on communication more evenly than less performing projects. These lower rated projects concentrated communication in the beginning and the end of the project.

Another finding concerning the channels through which information is transferred is the notion of 'gatekeepers' (Allen and Cohen 1969). Allen and Cohen (1969)

[5] Communication was only one of the factors studied. In fact, there were several more important factors explaining innovation success.

discovered that information from outside a laboratory enters the laboratory often via a two-step process. Stars in communication networks, called gatekeepers by Allen, collect information from external sources and distribute this information within the organization. Tushman (1977) found that such a two-step flow of information could also be found between interdependent units of a single organization, such as R&D and marketing. Tushman called this general phenomenon 'boundary spanning', an information processing structure suitable for dealing with uncertainty arising from interdependencies between units. Allen and Cohen (1969) and Tushman (1977) argue that the transfer of information across boundaries involves translating between different 'coding schemes'. Only some individuals have the ability to do that. Additional research showed that gatekeepers and boundary spanners are more important for development projects than for research projects. Allen et al. (1979) and Allen et al. (1980) report that external communication should be evenly distributed among researchers. In contrast to that, development projects benefit by having boundary spanners specialized in communication across boundaries. This can be explained by the fact that researchers communicate predominantly with other researchers, having the same coding schemes. Members of development projects need to communicate with different functions, such as manufacturing and marketing, which implies that different thought worlds need to be connected (Dougherty 1992).

Based on this review we can conclude that interpersonal technical communication is an important source of information for R&D staff and that communication has a positive effect on R&D projects. That suggests that it contributes to their practices. As Allen (1977: 110) states: "*The results are all in clear agreement: internal communication is of overwhelming importance. On the average the best source of information for an R&D engineer is a colleague in his own organization.*" The strength of the relationship between communication intensity and performance is contingent upon the task type involved and the persons with whom project members communicate. Some types of communication can even be detrimental. These effects on the performance of research and development make technical communication a topic worthy of study.

1.3.4. Explaining the use of personal communication

In addition to the degree of use of different sources, researchers have also focused on the factors influencing the use of particular sources. For the present study, it is particularly interesting why personal sources of information are used. Several explanations have been given for the reliance on personal and / or oral sources of information. An early study of Gerstberger and Allen (1968) showed that the accessibility and ease of use of an information source influence its use more than its perceived quality. This finding has been replicated regularly in the thirty years after the publication of their paper (Anderson et al. 2001). Gerstberger and Allen (1968) found that contacts within one's group and with experts within the wider laboratory were considered the most accessible and easiest to use information source. They hypothesize that that is an explanation for the heavy reliance upon them (see also Anderson et al. 2001). A second explanation is that some types of information are not available from published sources (Johnston and Gibbons 1975; Holland et al. 1976). This may include information about the availability of a service or expertise, customer requirements (Johnston and Gibbons 1975) and practical research knowledge such as special procedures and suggestions concerning pitfalls involved in the application of a given technique (Holland et al. 1976). A third explanation is that personal contact may provide additional emotional support and encouragement (Holland et al. 1976: 166; Glaser et al. 1983: 300). Another explanation has been provided by media richness theory (Daft and Lengel 1984). From writing, via telephone to oral communication, communication channels provide more opportunities for 'rich' communication. Rich communication is more able to solve ambiguities (Daft and Lengel 1984) or uncertainty about information (Holland et al. 1976). As Tushman (1978) states, *"oral communication is an efficient medium for the exchange of ideas, information, and concepts since it permits rapid feedback, recoding, and synthesis of complex information"*. Knowledge-based theories of organizing provide a fifth explanation. They argue that intensive personal interaction enables the sharing of tacit knowledge (e.g., Collins 1974; Kogut and Zander 1992; Faulkner and Senker 1995; Hansen et al. 1999), whereas written communication only enables the transfer of explicit knowledge.

1.3.5. The content of technical communication

While the sources and channels of technical communication in research have been studied thoroughly, the messages making up technical communication have received far less attention. Nevertheless, there is one unifying characteristic of these studies with regard to the content of technical communication. Before the 1990s it was common to describe this content as information (e.g., Herner 1954; Gerstberger and Allen 1968; Allen and Cohen 1969; Rosenbloom and Wolek 1970; Whitley and Frost 1973; Johnston and Gibbons 1975; Goldhar et al. 1976; Holland et al. 1976; Allen 1977; Tushman 1978; Gerstenfeld and Berger 1980; Shuchman 1981; Tushman and Scanlan 1981; de Meyer 1985; Keller 1994; Hertzum and Pejtersen 2000). This use of the notion of information to describe the content of technical communication is seldomly explicitly argued for. Though it has been argued that not all communication is necessarily information transfer. Tushman and Nadler (1978: 614) write: *"Information refers to data which are relevant, accurate, timely and concise. As information must effect a change in knowledge, data may or may not be information, and data processing may or may not be information processing"*. Sometimes the notion of 'ideas' has also been used (Baker et al. 1967; Utterback 1971; Rothwell and Robertson 1973). Since the recent outburst of interest in knowledge, the content of technical communication is more often identified as knowledge (e.g., Kogut and Zander 1992; Faulkner and Senker 1995; Grant 1996a; 1996b; Moenaert and Caeldries 1996; Hoopes and Postrel 1999; Hansen 1999; 2002; Hansen et al. 1999; Gupta and Govindarajan 2000; Bolisano and Scarso 2000; Stein and Ridderstrale 2001; Hansen and Haas 2001). A telling indication is found in Fisher and Fisher (1998: 280), where the index states: "*communication, see knowledge transfer*". Other studies mix the concepts of knowledge and information. It is currently common in organization science to treat information and explicit knowledge as equivalent (e.g., Kogut and Zander 1992; Preiss 1999; Birkinshaw et al. 2002).

Only a handful of studies have addressed the content of technical communication in more detail (see also the review of Moenaert and Souder 1990). Allen and Cohen (1969) distinguish three types of technical communication: technical discussion, getting critical incident information and getting research ideas. Johnston and Gibbons (1975: 31) present a more elaborate overview, refining an earlier taxonomy of Myers and Marquis (1969). Johnston and Gibbons distinguish between information about the existence or availability of equipment or materials with particular properties; properties, composition, characteristics of materials or components; test procedures and techniques; operating principles or rules, required specifications, technical limitations; location of information; theories, laws, general principles; design-based information; and existence of specialist facilities or services. Chakrabarti et al. (1983) distinguish four basic types of 'knowledge contents of information' that can be derived from communication channels and sources: new knowledge (theoretical, basic research, developmental research, applied research, production technology), indexes to knowledge (index/printed, information, index/consultants), derived knowledge (abstracts, summaries, reviews) and other types of knowledge (facts, how to information, current awareness, data). For both of these studies it is unclear how these categorizations are constructed. Faulkner and Senker (1995) identified over twenty different types of knowledge that can be derived from different sources. They base themselves upon the taxonomy of Johnston and Gibbons (1975) and the detailed empirical studies of Vincenti (1990). It is interesting to see that the different contents distinguished by these authors do seem to be different types of information or different types of knowledge (at least, their authors regard them as such). This seems to support the idea that what happens in technical communication is the transfer of information or knowledge.

Some studies have approached the question of the content of technical communication by focusing on the utility of information. Moenaert and Souder (1996) distinguish four dimensions of information utility: relevance, novelty, credibility and comprehensibility. Maltz (2000) speaks of timeliness in stead of novelty. If we accept Tushman and Nadler's (1978) claim that information consists of data that are 'relevant, accurate, timely and concise', these studies are about the informative value of messages. Whereas these authors study subjective perceptions of these utility dimensions, philosophers have thought about objective criteria for the value of messages. Social epistemologists have for example asked whether it can be justified to ground beliefs upon others' testimony (Coady 1992; Insole 2000) and whether it is reasonable to put (more) confidence in experts and authorities (Goldman 1999). These approaches seem to be concerned with fact-like or belief-like contents of communication.

1.3.6. Antecedents of technical communication

Given the importance of technical communication, either conceptualized as knowledge transfer or information transfer, it comes as no surprise that much effort has been put in the search for antecedents of its amount and success. These factors have especially been studied in the more recent knowledge management literature. In Appendix 4 I present an overview of the factors that have been found to influence, first, the frequency or amount of knowledge sharing and, second, the success of knowledge sharing. The success of knowledge sharing includes, in this overview, the ease of the process, the perceived value of what has been transferred and the use of information sources that are offered.

Appendix 4 indicates that many factors have been identified that influence knowledge sharing. Szulanski distinguished four types of factors, pertaining to the knowledge that is (to be) shared, to (potential) senders, to (potential) receivers and to the relationship between them. It is noteworthy that this classification resembles the elements of the source-channel-message-receiver model of communication. I added one other group of factors to these four classes. This fifth category consists of factors concerning the organizational context. With regard to the characteristics of knowledge, it is its degree of tacitness that is most often discussed as a factor influencing the amount and difficulty of knowledge sharing (e.g., Collins 1974; Kogut and Zander 1992; Szulanski 1996). This focus on tacit knowledge is a distinctive characteristic of knowledge oriented theories as opposed to information processing perspectives. It is claimed that information refers only to explicit knowledge. Characteristics of (potential) senders include their sources of motivation, their (perceived) expertise and their workload. Characteristics of (potential) receivers include their motivation to use new insights (including the Not Invented Here-syndrome), their absorptive capacity and their knowledge about who knows what. Relational properties that influence knowledge sharing are the amount of trust among organization members, a shared sense of identity and a common stock of background knowledge. An example of an organizational characteristic that is important is the organizational culture. It has frequently been claimed that knowledge management initiatives can fail due to an impeding culture (De Long and Fahey 2000). Probably the most well known finding of the study of communication in research is Allen's (1977) demonstration of the strong inverse relationship between the physical distance separating researchers and their frequency of communication. This overview indicates that the amount of knowledge sharing depends on many factors and that successful knowledge sharing requires the fulfillment of several preconditions.

1.4. Theoretical explanations

1.4.1. Information processing approach

In the preceding section I reported findings concerning the influence of technical communication on performance and contingency factors that act upon that relationship. Technical communication clearly contributes to industrial research practices. In this section I want to discuss theoretical explanations that have been given of this contribution. Both the information processing perspective and the KBT provide such an explanation. These explanations will take up a central place in this thesis. In this section I will discuss both of them, starting with the information processing approach.

The information processing approach, from now on abbreviated as IPA, has been developed by Galbraith (1973; 1977) and Tushman and Nadler (1978). They build on previous work of amongst others March and Simon (1958) and Thompson (1967). One core assumption of the IPA is that organization members face uncertainty. Not everything they should believe and do is known in advance. This uncertainty derives from three sources (Tushman and Nadler 1978). First, task characteristics yield uncertainty. This depends upon the complexity and predictability of the task. These dimensions are derived from Perrow's (1967) dimensions of the number of exceptions and the analyzability of these exceptions. A complex and unpredictable task yields more questions about what to do during the execution of the task and therewith more uncertainty. Second, task interdependencies provide uncertainty. Task interdependence means that the successful completion of one task depends upon the execution of another task. As organizations grow, they differentiate. Subunits are formed that have to perform distinct tasks. This specialization and differentiation results in various kinds of interdependencies between subunits. Galbraith (1977: 41) focuses predominantly upon uncertainty deriving from these interdependencies. Third, the environment of an organization yields uncertainty. But the organizational environment as a source of uncertainty will be left out of consideration in this thesis.

Galbraith (1973: 5) defines uncertainty as the difference between the information required to perform a task and the amount of information already possessed. Information processing can thus reduce uncertainty. A certain amount of uncertainty requires an equal amount of information processing. Galbraith (1973) distinguishes two basic strategies to deal with uncertainty. First, organizations can decrease the need for information processing during task execution. They can do this, for example, by creating self-contained tasks, having fewer interdependencies with other tasks. Second, organizations can increase their information processing capacity. Information processing can be enhanced by developing management information systems or by increasing communication. In line with other authors, Galbraith (1973; 1977) and Tushman and Nadler (1978) interpret technical communication as information transfer. Communication can both serve to reduce uncertainty stemming from task characteristics as uncertainty deriving from interdependencies (Allen 1986). If uncertainty stemming from task interdependencies is low, the coordination of tasks can be based primarily on other mechanisms: rules, hierarchy and planning. However, these mechanisms have not as much information processing capacity as communication has (Tushman and Nadler 1978: 618). Nevertheless, these other mechanisms should be used as much as possible. "*While the behavior of several thousand people must be coordinated, it is impossible for them to communicate with each other. The organization is simply too large to permit face-to-face communication to be the mechanism of coordination*" (Galbraith 1977: 41).

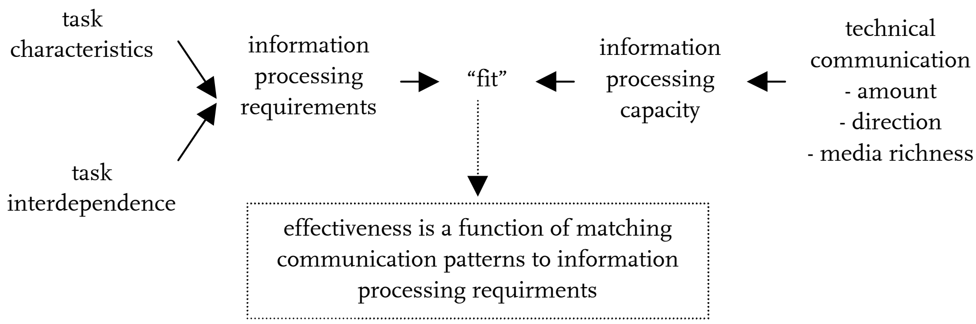

Figure 1.2: Outline of information processing model (based on Tushman (1978) and Daft and Lengel (1986))

The basic hypothesis of the information approach is that organizations should match their information processing activities to their information processing needs (see Figure 1.2). If the information processing capacity does not meet information processing needs, performance suffers due to residual uncertainty. If the information processing capacity exceeds information processing needs, too much time, attention and money will be spend on communication. This makes the IPA a clear example of a contingency approach (Keller 1994). The effect of communication on performance is contingent upon task characteristics, task interdependencies and the environment. The explanation for the value of technical communication in research is thus as follows: communication is the transfer of information; this information is able to reduce uncertainty; as long as there is uncertainty to reduce, this communication contributes to performance. This line of reasoning of the IPA is visualized differently in Figure 8.1.

Tushman and Nadler (1978) show how a wide range of previous empirical studies fit into this theory. The research of Tushman (1978; 1979) and others supports the general thesis of the IPA, which states that effective organizing requires the matching of information processing capabilities and needs. Tushman (1978) found that high performing projects with task characteristics that imply much uncertainty had significantly more intra-project communication than high performing projects that faced less uncertainty. Keller (1994) gives further empirical support. Keller determined that the fit between uncertainty and information processing (as measured by the total amount of communication) is a very good predictor of R&D performance. It explains more of the variance in performance than information processing does on its own.

The detailed findings from Appendix 3 do not only deal with the amount of communication, but also with the direction of communication. Correspondingly, the IPA describes information processing capacity also in terms of the direction of technical communication. If we want to explain the more detailed findings from Appendix 3, we need to introduce two supporting hypotheses. We may distinguish between communication that aims at reducing uncertainty stemming from task characteristics and communication that aims at reducing uncertainty stemming from task interdependencies. Such a distinction is proposed by Allen (1986), who differentiates between coordination-oriented communication and knowledge-oriented communication. Both are forms of work-related, technical communication. A first, quite trivial, supporting hypothesis is that knowledge-oriented communication should be directed toward those persons and groups that have the relevant information. "*Since project members often will not have all the appropriate information within their group, they must import information and ideas from outside the project*" (Tushman 1978: 628). A second supporting hypothesis is that communication oriented toward task interdependencies should be directed toward those persons and groups on whose tasks one's own task depends. With these supporting hypotheses in hand more evidence for the IPA can be found. For example, development projects depend more on other organizational functions than research projects do. As Appendix 3 indicates, the relationship between communication with the rest of the organization is positive for development projects, but not for research projects. On the other hand, research projects benefit more from contact with other researchers inside and outside the organization. It is reasonable to assume that those other researchers are indeed the sources of information needed to solve the problems inherent to research tasks. Tushman (1978) directly measured the interdependence between parts of the organization. For high performing projects he found a significant difference between the intensity of communication with strongly interdependent parts of the corporation and communication with weakly interdependent parts. Low performing projects did not show such significant differences. Interestingly, this was not found for intragroup communication. High performing projects had both a high degree of intragroup communication when they were dependent upon others in the group and when they were not dependent upon others (Tushman 1978: 639). This may be due to the fact that intragroup communication is not oriented toward resolving interdependencies but oriented toward resolving uncertainty inherent in the research task characteristics.

A final characteristic of technical communication that determines information processing capacities is the richness of communication channels. This factor is introduced by media richness theory (Daft and Lengel 1984; 1986). According to Daft and Lengel, organizations do not only face uncertainty but also equivocality or ambiguity (Weick 1979). Equivocality and ambiguity refer to the existence of multiple interpretations of messages and situations (Daft and Lengel 1986). Information processing should therefore not only reduce uncertainty, but also ambiguity and equivocality. Ambiguity should not be resolved by more information, but by richer forms of communication (Daft and Lengel 1984). Matching information processing activities to information processing requirements requires not only a certain amount of communication and a particular direction of communication but also a particular richness of communication (see Figure 1.2).

1.4.2. Knowledge-based theory of the firm

Grant's (1996a; 1996b; 1997; 2001) elaboration of the knowledge-based theory of the firm resembles aspects of the information processing approach. Unfortunately, no systematic attention has been paid to similarities and differences, nor has an attempt been made to integrate both views. Whereas organization scientists have developed the IPA, economists have contributed as well to the development of the KBT. The KBT has a broader scope. One of the central tenets of the knowledge-based theory is that it aims to explain the existence of firms. Kogut and Zander (1992: 384) present the KBT as an alternative for transaction cost economics. Kogut and Zander (1992; 1996) consider firms as communities that are specialized in the transfer and creation of knowledge. According to Grant (1996a: 375) the primary role of firms is the integration of knowledge. Firms are much better equipped for this integration of knowledge than markets are. Grant bases his theory on Demsetz's (1991) observation that the acquisition of knowledge requires that individuals specialize in specific areas of knowledge, while the application of knowledge to produce goods and services requires the bringing together of many areas of specialized knowledge (Grant 1996a: 376; 1997: 451). No individual is capable of learning everything that is necessary to develop and produce complex products. Individuals have restricted learning capacities. Their information processing capacities are limited (Simon 1991). But whereas the acquisition of an adequate knowledge level requires individual specialization, many production and development processes require the application of a wide range of knowledge (Demsetz 1991; Grant 1996b; Tsoukas 1996). This fundamental asymmetry between knowledge acquisition and knowledge application has as a consequence that organizations have to integrate dispersed bits of specialized knowledge held by individuals. Grant claims that the capabilities of organizations, their competencies, arise out of the integration of specialized knowledge of individuals. Take for example a theatrical performance. In a play, it is especially important that an individual's knowing how to play a role fits with the other player's knowing how to play their role. A particular interpretation of a line of text is quite meaningless outside the context of a play, but may be contributory or detrimental within that context. According to Grant it is especially this integration that is difficult to realize and replicate. It is the integration of knowledge that is the primary task of organizations and that determines their performance.

There are interesting parallels between the idea that knowledge integration lies at the core of organizing and the concept of distributed cognition (Hutchins 1991a; 1991b; 1995; Salomon 1993; Madhavan and Grover 1998). The concept of distributed cognition refers to the division of cognitive labor (Hutchins 1995). Cognitive tasks, such as observing, reasoning and memorizing, can often not be executed by a single person. This can be attributed to the facts that human information processing capacity is limited (Simon 1991) and that the required knowledge is distributed over organizational members (Tsoukas 1996). A central claim of the perspective of distributed cognition is that the cognitive performance of groups and organizations does not only depend on the qualities of individuals, but also on the way individual cognitive activities are differentiated and integrated. The KBT and the literature on distributed cognition are united in the view that the performance of organizations is to a large extent dependent upon the way they handle the process of knowledge integration, or, in general, organize distributed knowledge and cognition.

Drawing upon Thompson (1967), Van de Ven et al. (1976) and Demsetz (1991), Grant (1996a; 1996b; 1997) distinguishes different knowledge integration mechanisms. Grant (1996a) distinguishes direction and routines as knowledge integration mechanisms. In his 1996b paper he expands this to: (1) rules and directives; (2) sequencing; (3) routines and (4) group problem solving and decision making. In his 1997 paper the last mechanism is identified as transferring knowledge. These different integration mechanisms will be discussed in more detail in chapter seven. It should be noted that Grant uses a broad notion of knowledge integration. According to him, knowledge is integrated when distinct pieces of knowledge are applied in such a way that they result in a product or service, which would have been unable to deliver without the application of each of those pieces of knowledge. Take the following example. Two tasks, A and B, have to be executed sequentially to make a certain product and person 1 knows task A and person 2 knows task B. If they execute their own tasks, this results in a sound product. In this production process their knowledge is integrated (in the product), even if they work in isolation. Sequencing, like in an assembly line, is therefore one type of mechanism to integrate knowledge. We might call this an indirect integration of knowledge, in contrast with the direct integration of knowledge that happens when two pieces of knowledge are integrated in someone's head. Transferring knowledge can bring about such a direct integration of knowledge. But Grant notes that "*transferring knowledge is not an efficient approach to integrating knowledge. If production requires the integration of many people's specialist knowledge, the key to efficiency is to achieve effective integration while minimizing knowledge transfer through cross-learning by organizational members*" (1996b: 114; emphasis in original). Because especially the transfer of tacit knowledge is very difficult, efficiency in organizations tends to be associated with maximizing the use of rules, routines and other integration mechanisms that economize on communication and knowledge transfer. Like transaction cost economics view firms as the governance structure "*of last resort, to be employed when all else fails*" (Williamson, quoted in Osterloh and Frey 2000: 539), Grant views knowledge transfer as a last resort, to be employed when other knowledge integration mechanisms fail (Grant 1996b). This is in line with Galbraith (1973) who claims that communication should be avoided as much as possible. But despite of, or due to, its being the last resort of the last resort according to some economists, empirical research has found communication to be of utmost importance for industrial research (see section 1.3.3).

Knowledge-based perspectives in the field of organization science associate technical communication first and foremost with knowledge transfer. The direct use of the transfer of knowledge is frequently identified as the avoidance of reinventing the wheel (e.g., Bender and Fish 2000: 130) and sometimes as a means of coordination (e.g., Hoopes and Postrel 1999).[6] The KBT, especially in Grant's elaboration of it, interprets these functions on a more abstract level. It views knowledge sharing as one of four possible mechanisms of knowledge integration. Knowledge integration is central to the performance of an organization. Their basic explanation of the value of technical communication in research therefore seems to be that it is a means of integrating knowledge. In technical communication, researchers receive knowledge they need but did not possess before. However, as stated above, knowledge transfer is considered to be not a very efficient way of integrating knowledge. That makes this explanation not fully satisfactory – at least not at first sight.

The integration of knowledge can be necessary both in production and in exploration. Knowledge creation, for example in product development, also requires the integration of specialized knowledge. Nonaka (1994) argues that the sharing of explicit and implicit knowledge is essential for organizational knowledge creation. In the organizational learning literature it is emphasized that individual learning results should be transferred to others to turn into organizational learning. Knowledge sharing is considered to be an integral part of organizational learning (Shrivastava 1983; Huber 1991; Kim 1993; Andrews and Delahaye 2000). By sharing newly created knowledge, knowledge can be integrated at several places.

It is interesting to wonder in what ways the KBT differs from the IPA. It would digress me too much now to explore that question thoroughly. Nevertheless, I want to make some comments upon it. The coordination mechanisms Grant distinguishes resemble the four mechanisms Tushman and Nadler, based on Thompson and Galbraith, distinguish: rules and programs; hierarchy; joint planning and information and communication systems.[7] There is one big semantical difference: Grant identifies these coordination mechanisms as mechanisms to integrate knowledge, whereas Galbraith and others identify them as mechanisms to integrate tasks. It is unclear to what extent this semantical difference reflects real differences. A clear difference between the IPA and the KBT is the latter's focus on tacit knowledge. Another difference is that uncertainty reduction seems to presuppose existing uncertainties, existing questions, existing problems and existing environments. The KBT is also concerned with the development of problems (Nonaka 1994). It has more to do with

[6] I know of no author who has distinguished these two goals. But, interestingly, they correspond to the two functions of technical communication discerned by the information processing approach: decreasing task-based uncertainty and decreasing uncercainty stemming from interdependencies.

[7] There are some differences in wording. It is not clear whether these differences are intended to refer to substantial differences or not.

enacting one's own world (Daft and Weick 1984) than only with adapting to an existing world.

1.5. The process of technical communication

1.5.1. Meaning and context

Several critiques, extensions and alternatives have been developed with regard to the linear communication model. I will not give an exhaustive review of communication models (see Putnam et al. 1996; Krauss and Fussell 1996). I will concentrate on issues that have been underexposed in linear communication models, but are important to acknowledge in empirical research. These include the bi-directional nature of communication, the importance of meaning and interpretation and the role of the context of communication. Although most of the literature reviewed up to this point has been inspired by a linear communication model, I do not think that this research needs to be rejected when the linear communication model is rejected. Some of the possible critiques on linear communication models have been acknowledged in these studies and I will show below that the innovation and knowledge management literatures have contributed to an enhancement of our understanding beyond linear communication models as well. However, two other streams of research, situated learning and ethnographic science and technology studies, have typically focused on the factors neglected in the linear communication model. Therefore I will draw more upon these streams in this section.

A first critique is that linear communication models fail to account for the two-sided nature of communication (Rogers and Kincaid 1981). Meijers (2002) argues that the collective nature of dialogical communication cannot be captured by applying a one-way communication reciprocally. According to Meijers, dialogical communication draws on a collective intention to communicate and yields a shared understanding in a way that cannot be captured by a linear communication model. In line with these critiques, alternative models of communication have been developed, which center around the creation of shared understanding (e.g. Rogers and Kincaid 1981; Habermas 1981; Meijers 2002). In stead of arguing dichotomously about communication models, it might also be argued that different models pertain to different communication types. Linear communication models might be adequate for mass communication, such as broadcasting or road signs.

A second issue that is underexposed in linear communication models is the importance of meaning and interpretation. Shannon and Weaver (1949) discuss the coding and decoding of messages, but refer to the transformation of, for example, characters in electrical pulses. Their use of the concepts coding and deconding does not concern the meaning of messages. Proponents of linear communication models have been accused of treating the effect of communication like an injection with a hypodermic needle. But words do not carry their meaning like a container carries products. Receivers have to reconstruct meanings (Reddy 1979). In the innovation and knowledge management literatures this is acknowledged by focusing on the importance of shared conceptual schemes or the capability to translate one conceptual scheme into another (Tushman 1977). In relation to that, the importance of common knowledge and 'absorbtive capacity' have been stressed (e.g., Cohen and Levinthal 1990; Kogut and Zander 1992; Grant 1996a; Lane and Lubatkin 1998). Furthermore, Gherardi and Nicolini (2000) show how meanings may be transformed in the process of communication. Meanings may be interactively constructed in communication (Boden 1994: 18). According to Knorr-Cetina (1981; 1995), ethnographic studies of scientific laboratories have shown that communication within laboratories is essentially a process of negotiation. During the research process all kinds of decisions have to be made. Do we use this method or that? This material or that? According to Knorr-Cetina (1981), there is no universally applicable set of methodological rules that can be applied to answer such questions. They require local negotiations. In communication researchers negotiate about the validity of knowledge claims and effectiveness of actions. Latour (1987; Latour and Woolgar 1979) views communication in science as an antagonistic process. It consists of statements struggling for domination. A statement can take the general form 'A is B', uttered or written down by someone. Negative and positive modalities can be attached to this statement: 'this experiment suggests that A is B' or 'it has been proven that A is B'. The name of the author can be attached to the statement: 'John says that A is B' or just 'A is B'. A fact is characterised by the deletion of all modalities and references to the context of its production. As such it may be found in the handbooks on the subject or it might be incorporated in scientific instruments. It becomes a 'black box'. It's meaning has become fixed.

Latour's discussion of communication in science brings us at the importance of the context of communication. According to Latour, to turn a statement into a black box, a statement needs the backing of a network of other statements, human actors with power and interests, and material objects. To call a statement-turned-fact into a mere statement again, to open a black box, one should attack its supportive network as well. In general, social constructivistic sociologists of science have particularly stressed the influence of social factors like power, interests and networks on scientific communication and knowledge development (e.g., Barnes and Bloor 1982; Collins

1983; Latour 1987).[8] Another perspective that has explicitly taken into account the context of knowledge sharing and learning, is the situated action and situated learning approach, which has also become influential in organization studies (e.g., Orr 1990; Lave and Wenger 1991; Brown and Duguid 1991). Studies of midwives, tailors, quartermasters, butchers and non-drinking alcoholics show how the learning process of apprentices consists of much more than a simple transfer of knowledge. Knowledge sharing is inextricably interwoven with the social and physical context. According to Lave and Wenger (1991), learning a job is essentially becoming a member of a community of practice. The acquisition of tacit and explicit knowledge, the execution of tasks, the development of social relationships and the development of identity are inextricably interwoven. This situated nature of learning and knowledge sharing was also found in studies of Orr (1990) and Cicourel (1990). Cicourel (1990) describes interactions between medical specialists. Their discussions around a diagnosis cannot be considered solely from a cognitive point of view. An important function of these knowledge sharing interactions is to present oneself as a competent member of a community. In line with Cicourel (1990), Orr concludes that telling 'war stories' by photocopier repair technicians, stories about critical incidents, is a way of constructing and 'celebrating' their identity as group members. In addition, innovation and knowledge management studies have concentrated on context factors influencing the process and amount of knowledge sharing and technical communication (see Appendix 4). These include the similarity of activities and

[8] For several reasons the perspective of social constructivistic science and technology studies played a minor role in this study. First, my study is located in the field of organization science. Therefore the focus was on two important perspectives in that field: the IPA and the KBT. A major difference between social constructivistic science and technology studies and the innovation management and knowledge management literatures, is that these science and technology studies do not link research practices to some measure of performance. They are interested in explaining why a particular scientific theory has triumphed in a controversy, how consensus ('closure') has been reached (e.g., Pinch and Bijker 1987). According to Bloor (1976: 5) sociologists of science should be impartial with respect to truth and falsity, success or failure. In stead of deciding what is efficient or effective, Latour (1987: 9) states that science and technology studies should focus on the way performance criteria are constructed. Second, I did not follow the process of constructing knowledge, but single interactions. Third, I do not belief that we should limit ourselves to social factors when explaining the construction of knowledge, as Latour (1987: 258) would have it. I follow sociological studies in considering knowledge development in research to be a collaborative affair, but I belief that social and cognitive factors should be studied in an integrated fashion. Empirical support for such a perspective is offered among others by Garud and Rappa (1994), Rappa and Debackere (1993) and Debackere and Rappa (1994). Philosophical proponents of an integrated perspective on social and cognitive factors are Thagard (1993; 1994), Giere (1999) and Goldman (1999). Furthermore, I have followed sociologists of science by studying communication in the context of science-in-action.

strategic similarity (Brown and Duguid 1998; Lane and Lubatkin 1998; Hislop et al. 2000), the similarity of identity (Galunic and Rodan 1998), organizational structure and culture (Menon and Varadarajan 1992; Moenaert et al. 2000) and the occurrence of organizational crises (Van der Bij et al. 2003).

A final point that can be learned from situated learning studies and sociologists of science is that communication is an integral part of work-practices. It is not just that contexts influence communication. In reference to the work of Orr, Brown and Duguid (1991) argue that communication is an integral part of ongoing work practices (Brown and Duguid 1991). Work practices are inextricably connected to their context. Communication in work settings should therefore be studied and interpreted in the context of those work settings. The same point is made by Lynch (1985) in his ethnography of a scientific laboratory. He found that laboratory 'shop talk' is inseparable from its physical, social and work context. Even stronger, talk should be regarded as an integral part of work.

1.5.2. Speech act theory

The previous section described some additional insights in the process of technical communication that influenced my theoretical sensitivity (Glaser 1978). In this section I will discuss a perspective that has particularly influenced my pre-understanding: speech act theory. My study focused on the contribution of technical communication to industrial research practices. For that reason, I was predominantly interested in pragmatics, and less in syntactics or semantics. Pragmatics is the study of the use of language in human interaction (Mey 1993). One of the central theories in pragmatics, a theory that has spurred pragmatics as a field of inquiry, is speech act theory. Speech act theory particularly influenced my theoretical sensitivity in this study and therefore I will discuss it in some detail.

Speech act theory is inspired by the later Wittgenstein (1953), initiated by Austin (1962) and developed further by Searle (1969; 1979). The core of speech act theory is expressed in the title of one of Austin's publications: *How to do things with words* (1962). Austin noticed that, by using certain phrases, we simultaneously do what we say and say what we do. Take for example the utterance: 'I promise to bring that book to you'. If someone utters that sentence, he does not describe a state of affairs and does not make a prediction. He promises. He commits himself to something. It is not an utterance that can be evaluated in terms of truth. By uttering the sentence, it is made true. By saying 'I walk', one does not automatically walk. But by saying 'I promise', one promises. The same phenomenon occurs with verbs like commanding and apologizing. Searle (1969) recognized that it is not only in such special cases that we are doing something with words. In all communication we do something with words. When we do something with words, this is called a speech act. According to Searle, speech acts are the basic units of communication (Searle 1979: 178). Searle (1979) distinguishes five types of speech acts: (1) assertives, in which something is said about the world (e.g., describing); (2) directives, attempts by the speaker to get the hearer to do something (e.g., commanding); (3) commissives, in which the speaker commits himself to some future course of action (e.g., promising); (4) expressives, in which a psychological state is expressed (e.g., apologizing); and (5) declarations, by which a state of the world is realized (e.g., appointing someone chairman).

A speech act is a combination of four different acts (Searle 1969: 24): (1) an utterance act, i.e., uttering certain words; (2) a propositional act, i.e., attributing properties to an object; (3) an illocutionary act, i.e., what is done in saying it (commanding, requesting, apologizing); (4) a perlocutionary act, i.e., bringing about a certain effect in the listener. Take for example the sentence: 'Close the door!'. Uttering these words is the utterance act. The propositional act is to attribute the predicate 'is closed' to 'door'. The illocutionary act is a command. The perlocutionary act is to make someone close the door. The effect of a perlocutionary act is called the perlocutionary effect. The influences which communication has on interlocutors are thus perlocutionary effects.

Speech act theory is a particularly useful perspective for this study since it focuses on what is done in communication. The notion of a speech act can be considered a sensitizing concept in this study. Together with the insights in communication described above, for example, that we should study communication in its real life context, it guided the execution of the present study.

1.6. This study

1.6.1. Identification of research problems

One major conclusion that can be drawn on the basis of past research is that technical communication contributes to industrial research practices. Researchers rely heavily upon personal sources and channels of information, i.e., upon technical communication with their colleagues. Technical communication with colleagues contributes to a researcher's performance and to the performance of a project team or department. However, based on the literature review, three problems concerning the contribution of technical communication to industrial research can be identified: (1) the content of technical communication has been underexplored, i.e., the details of the contribution of technical communication to industrial research practices have been underexplored; (2) the way technical communication and its contribution to research practices is realized is not fully explored; (3) the first two points imply that the interpretation of technical communication as information transfer and / or knowledge transfer, and the broader interpretations of its contribution to research practices offered by the IPA and the KBT are not based upon empirical research into the details of technical communication. I will discuss these points below.

A first issue that is not well understood is the content of technical communication (see section 1.3.5). We have learned that technical communication contributes to research practices, but we know little about the particular ways in which it does so. The majority of studies have only focused on the amount and direction of communication. For example, Tushman (1978) and Allen (1977) asked their subjects to specify with whom they had work-related contact on a particular day, and repeated this for a number of days. As Tushman (1978: 630) acknowledges, this method only measures the number of work-related contacts between individuals. It does not get at the meaning, content or the quality of the interaction. Likewise, many studies of knowledge transfer restrict themselves to the measurement of the amount and direction of knowledge transfer (by means of single-shot questionnaires) (e.g., Hansen 2002; Birkinshaw et al. 2002). This means that there is limited insight in the ways in which technical communication actually contributes to industrial research practices.

A second second problem concerns the ways in which the content of communication is realized. In general, several authors have noted the lack of research into the human interactions in which knowledge sharing takes place (e.g., Grant 1996a: 384; Hertzum and Pejtersen 2000: 762; Andrews and Delahaye 2000: 799). One aspect of the process of technical communication that is not well understood is its relationship with the content of communication. If we would accept the claim that the content of technical communication is information or knowledge, this still presents us with a problem. It is interesting to compare the collection of money with the collection of information. We might measure the collection of money in euro's and the collection of information in bits. In collecting euro's, it does not matter which euro one receives. One euro is one euro. However, it matters which bits one receives. One bit may tell something else as another bit. One bit is not another bit. Some bits might be useful, others not. Given that the usefulness of communication is not obvious, the question rises how researchers realize useful communication. This question cannot be answered by referring to the factors influencing technical communication and knowledge sharing, summarized in Appendix 4. These factors enable and constrain technical communication and knowledge sharing, but do not explain how technical communication is initiated. This issue gets more and more important, since there is a tendency away from information scarcity to information overload in contemporary organizations (Hansen and Haas 2001). In science and research and development this problem has been faced earlier (Garvey and Griffith 1964; 1967; 1971; de Solla Price 1963). Allen (1977: 7) writes: *"The tremendous increase in recent years in the amount of R&D performed in the world has resulted in a concomitant increase in the amount of information to be communicated, presenting the user with the difficult problem of plowing through a morass of available information to reach the information pertinent to his problem."* Huber (1991: 107) noted in a review on organizational learning that the way organizational units possessing information and units needing this information find each other quickly and with a high likelihood, is left unexplored. The 'search'-phase, considered as an essential part of knowledge sharing by Hansen (1999) and the 'initialization'-phase discerned by Szulanski (1996; 2000) can be considered as attempts to answer this question. However, neither of these authors has explored these phases in depth.

A third problem is that the explanations of the value of technical communication offered by the IPA and the KBT have not been based on in-depth qualitative studies of technical communication. In short, the IPA states interprets technical communication as the transfer of information, which reduces uncertainty and ambiguity stemming from task characteristics and task interdependence. As Van de Ven and Drazin (1985: 354) note, the concept of information is treated as an abstract, latent, unmeasured concept in the empirical research of IPA theorists. The KBT interprets technical communication as knowledge transfer and considers this to be a mechanism for the integration of knowledge. Grant (1996b) calls for detailed empirical studies of knowledge transfer and knowledge integration in order to advance the understanding of the KBT of these processes. Eventual findings about the content and process of technical communication might therefore have implications for the theoretical interpretations of the contribution of technical communication offered by the KBT and the IPA. We may ask whether technical communication can indeed be identified as information transfer and / or knowledge transfer. Likewise, the broader explanations of the contribution of technical communication, as a means for the reduction of uncertainty and ambiguity associated with tasks, and as a means for the integration of knowledge may be questioned as well.

1.6.2. Objectives of this study

Defined broadly, this research intended to contribute to the development of theory on knowledge processes in organizations. Management oriented literature on knowledge in organizations (e.g., Nonaka and Takeuchi 1995; Davenport and Prusak 1998) presents models, guidelines and tools to advance these processes. Theory oriented literature tries to understand these processes, their value and their antecedents and may therewith inform the design of management instruments. This thesis contributes to the theory-oriented literature. Hopefully it informs the future development of management instruments.

More specifically, the objective of this study was to fill the gaps in the literature identified above. The first empirical objective of this study was to gain insight in the content of technical communication in industrial research and the way this content relates to researchers' work practices. The second empirical objective was to get insight in the different ways in which technical communication gets realized and the way this influences its contribution to research. Taken together, this asked for the development of empirically grounded theory on the ways in which technical communication contributes to industrial research practices and the ways in which this is realized.

In addition to these empirically oriented goals, this study had an important theoretical goal. The third problem identified in the previous section concerned potential implications of more detailed insight for the IPA and the KBT. Therefore I also reflected on the implications of empirical findings for the KBT and the IPA. Both these theories provide a theoretical interpretation of the contribution of technical communication to industrial research. A central objective of this study was to show in what ways and to what degrees detailed empirical findings concerning the contribution of technical communication to industrial research support, contradict or extend the IPA and the KBT.

In this thesis I will take alternately an empirical and a theoretical stance. The underlying approach is that conceptual and theoretical questions will be discussed on the basis of empirical results. Under-researched issues require an open, exploratory approach. Correspondingly, I did not start with an elaborated theoretical framework. Of course, it might be argued that all understanding is necessary theoretically prejudiced. It is a fiction that it is possible to do research as a *tabula rasa*, as an immaculate piece of photographical paper, waiting to be exposed to the light of reality. Our pre-understanding enables our interpretations. My pre-understanding is influenced among others on the reviewed literature. For example, I took it to heart that full insight into the role of technical communication can only be realized by studying it as a part of the actual practices of organization members.

The plan of this thesis is as follows:

- Chapter two describes the research approach taken in this study and the methods and techniques that were employed.

- Chapter three presents the organizations in which I carried out my empirical research.

- Chapter four is the first empirical chapter and addresses especially the first research problem. The results presented in that chapter concern the contributions of technical communication to industrial research practices.

- Chapter five is the first theoretical chapter. Based on results presented in chapter four, I will explore if, or to what degree, technical communication can indeed be interpreted as information transfer or knowledge transfer. Another basic assumption of the IPA, that communication reduces uncertainty or ambiguity, will be scrutinized as well.

- Chapter six is the second empirical chapter, addressing the second research problem. This chapter will be focused on the way researchers realize technical communication and the influence this has on the contribution of technical communication to research practices.

- Chapter seven is the second theoretical chapter. The empirical findings about technical communication will interpreted in terms of knowledge processes and distributed cognition. These interpretations will be used to reflect upon the KBT.

- Chapter eight summarizes the findings and conclusions of this study, reflects upon choices made and offers suggestions for future research.

2.

RESEARCH APPROACH

This chapter describes the empirical research that was undertaken to investigate the contribution of technical communication to industrial research practices and the way this contribution is realized. In the first section I will argue these issues require an open, and exploratory, yet structured approach. Based upon these demands, the grounded theory method was chosen. The grounded theory approach guided data-collection and data-analysis.

The second section of this chapter contains a reflection upon the nature of social reality and the implications this has for the study of social reality. I will argue that the study of a social phenomenon like communication requires both an interpretative and a detached stance.

The next sections describe the details of data-collection and analysis:

- *the empirical focus was on research-related communication between researchers in two industrial research groups*
- *the approach to data-collection can be characterized as passive participant observation*
- *observation, interviews, pre-hoc and post-hoc discussions of interactions and document analysis were used for data-collection*
- *data were first analyzed qualitatively according to the coding procedures of the grounded theory approach*
- *in a later stage, part of the data was analyzed quantitatively as well*

This chapter ends with a reflection on the quality criteria controllability, reliability and external and internal validity. Care has been taken to meet these criteria, except for external validity, but the exploratory and predominantly qualitative nature of this study yielded some limitations as well.

2.1. Introduction

This study has focused on the ways in which technical communication contributes to industrial research and the ways in which this is realized. These issues were dealt with by empirical inquiry and theoretical reflections. The empirical part of this study took an exploratory, qualitative approach. The study concentrated on theory development and not on theory testing. The aim was to gain grounded insight into rather underexplored issues. Explorative research is enhanced by a qualitative approach. The adjective qualitative is used in different ways in the literature. It is often used to refer to research that uses textual data and does not reduce these textual data to numbers. Other authors use the adjective qualitative in a more encompassing sense (Denzin and Lincoln 1994). For them, it refers to interpretative research – research that aims at understanding subjects and their lifeworld. In a third interpretation of 'qualitative', it refers to research that focuses on discovering qualities, properties of phenomena. In this sense, natural science research can be qualitative as well (see Casimir 1983). The present study was qualitative in all three senses of the word - at least to a large extent. It shared characteristics with ethnography and ethnomethodology. Ethnography is the in-depth study of the life-world of a group of people (Hammersley and Atkinson 1983). Ethnomethodological studies concentrate on the methods by which members of a particular group accomplish certain tasks (Garfinkel 1967). In this research the focus was on the ways in which researchers realize technical communication. By taking this qualitative approach, I followed the advice of Moenaert and Caeldries (1996: 308), who claim that "*more qualitative approaches are needed to gain a more in-depth insight into the flows of information in the organization.*" But, as will be discussed in section 2.4.3, some quantitative analyses were performed too.

King (1994) puts qualitative methods of analysis on a continuum from structured to unstructured. Quasi-statistical approaches like content analysis are the most structured. The least structured approach is called 'immersion / crystallization' by King. This approach thrives on intuitive analyses. In between are the grounded theory approach (Glaser and Strauss 1967) and the more structured template-approach (e.g., Miles and Huberman 1984). The template-approach and the quasi-statistical approach require that the researcher has a clear picture of what he aims to study. He needs to have (at least some of) his concepts in advance. Therefore these approaches were not suited for this study - at least not in its primary stages. Following the advice 'work as structured as possible', the grounded theory approach seemed to be a good option. For that reason, this approach was used in this study. But later parts of the analysis were more structured and resembled the two more structured approaches.

The grounded theory method fits an open, qualitative, explorative approach. Glaser and Strauss developed its outlines in the 1960s. They published first about it in their book *The discovery of grounded theory* (1967). In later publications they refined their method. From a certain point in time, Glaser and Strauss elaborated the grounded theory approach independently of each other (Glaser 1978; Strauss and Corbin 1990). Eventually, Glaser accused Strauss of betraying the 'real' grounded theory principles (Glaser 1992). When all was still peace and quiet, they observed that the by then current methodologies focused for the most part on theory testing (Glaser and Strauss 1967). But theory testing presupposes existing theories. However, methodologies for the development of theory were themselves ill developed. As a result of that, they claimed, theories were mainly developed by armchair theorizing. Glaser and Strauss (1967) aimed at resolving this deficiency by constructing guidelines for the development of theory. Their grounded theory approach is a way of systematically crafting theory out of empirical data. The systematic nature of the grounded theory approach contrasts with purely intuitive analyses. Although analysis will never become fully objective or independent of the analyzer, the grounded theory approach tries to make the process of analyzing more controllable and less subjective.

The grounded theory approach is meant to yield theories that are grounded in data. The notion of a theory refers to a coherent whole of concepts and relations between those concepts. In line with that, the grounded theory approach aims at constructing concepts and relationships between concepts. The grounded theory approach is an inductive method. It aims at constructing a generalizable theory based on a limited set of data. In other words, it is a bottom-up approach. Hypotheses are not derived from higher level theories, but from empirical data. Currently the grounded theory approach is predominantly used to analyze qualitative data. Nevertheless, its original formulation did explicitly leave room for the use of quantitative data. It is certainly possible to work with both types of data within the grounded theory method.

The grounded theory approach is meant for open, exploratory investigations. Likewise, I did not start with an elaborated theoretical framework. But to develop grounded theories, a researcher should not forget everything he knows, make his head empty, when starting a study. No researcher is like a *tabula rasa*. We all start our research with certain pre-conceptions (Gummeson 1991). The development of theory is aided by theoretical sensitivity (background knowledge about what might be important in the area of study) and sensitizing concepts. Some of this pre-understanding concerns basic knowledge of one's society and language. That basic knowledge enables a researcher to use himself as a research tool. Naturally, the literature reviewed in the first chapter has influenced my theoretical pre-understanding and theoretical sensitivity. For this study previous insights in communication, knowledge and knowledge processes were particularly relevant. Concerning communication, speech act theory and the insight that communication needs to be studied in the context of actual work practices were guiding. Further, the concepts of knowledge and knowledge processes enabled this study. The concept of knowledge will be further explored in chapter five, which is the chapter in which I particularly need a sharp definition of knowledge. One issue that needs to be discussed before I proceed is the nature of social reality. The characteristics of social reality have implications when a social phenomenon like communication is taken as object of study.

2.2. Studying social reality

Social reality does not exist in the same way as physical reality does. There is a fundamental difference between rocks, atoms and trees on the one hand and driver's licenses, money and marriages on the other hand. Social reality is created by humans and exists only in so far as human actors maintain it (Searle 1995). A rock would also be a rock without us. The properties of a rock that are independent of us may be called 'intrinsic properties' or 'brute facts' (Searle 1995: 10). Although the concept of 'rock' is ours, attaching that concept to an object does not alter its properties. But without humans, a euro note would only be a piece of paper. For it to be a euro note, we need to attach a function to it and have particular beliefs about it. If we would not have the shared belief that a certain piece of paper is a euro note, because we know that is has been printed by a counterfeiter in stead of an approved institution, it would not have the function of money. We construct social reality by attaching meaning to ourselves and the world surrounding us, and acting upon that meaning (e.g., Berger and Luckmann 1966; Giddens 1984). This makes social reality a pre-interpreted reality. A researcher is never the first to discover it.

However, as Giddens (1984) notes, humans do not construct reality from scratch. They find themselves always amidst an existing social structure and an existing physical world. On the one hand, social structures are produced and reproduced by humans. On the other hand, structures influence actions. Structures are both the product of and the means for human actions. For example, the existence of the institution of universities, enabled me to become a Ph.D.-student and to work on a Ph.D.-project for five years. According to Giddens' structuration theory (1979; 1984), the influence of social structures is both enabling and constraining. Take for example the game of football. Existing rules, created and maintained by humans, enable playing a match. The rules enable that we arrive at a final score and not at chaos. But the rules constrain actions as well. A field player is not allowed to play with his hands, to curse at the referee and to adjust the scoreboard in his advantage. However, actions are never determined by existing rules. We have the freedom to do otherwise

(Giddens 1984). The options to generate, follow and deviate from social rules are enabled by the knowledgeability of humans. Knowing a rule makes it possible to follow it or deviate from it. But humans are not completely knowledgeable. They follow rules they are not consciously aware of. Giddens calls this 'unacknowledged preconditions'. In addition, human actions have unintended consequences. For example, Newell et al. (2000) describe how the implementation of a range of intranet projects in an international banking and insurance company, intended to connect dispersed departments, had the ironic and unintended consequence that the trenches between departments became deepened, due to the fact that the intranet projects themselves were not well connected.

These ontological properties of social reality have implications for the study of human interaction. Since social reality is created by the meaning systems of those involved, we need to understand those meaning systems when we want to understand social reality. The knowledgeability of community members can serve as our source of information to learn about their actions, artifacts and institutions. This calls for a process of interpretation. Philosophers of social science called this process 'verstehen' (Gadamer 1960; Habermas 1981). Although such an interpretative stance is a necessary pre-condition for social scientific research, not all questions concerning social reality can be answered by interpreting the meaning systems of its participants. Although human actors are knowledgeable, they are not completely transparent to themselves. They follow rules of which they may not be consciously aware. Further, their actions may have unintended consequences and consequences they are unaware of (Giddens 1984). Therefore, social scientists should also look further than the self-interpretations of the subjects studied. Social research calls for both involvement and detachment (Elias 1956). Different research traditions put varying emphasis on these two poles. In social science in general, and organization studies in particular, this has even led to the idea that these different approaches constitute incommensurable paradigms (Burrell and Morgan 1979; Denzin and Lincoln 1994). Irreconcilable oppositions have been supposed to exist between 'subjectivism' and 'objectivism', 'interpretation' and 'explanation', 'hermeneutics' and 'social constructivism' versus 'functionalism' and 'positivism', 'emic' versus 'etic', etcetera (e.g., Jackson and Carter 1991). The vigorous debate between such positions has turned into a 'paradigm war' according to some authors. But, in line with Giddens (1979; 1984) and Weaver and Gioia (1994), I consider it to be merely different accents on two complementary aspects of social reality.

Based on these discussions, it is possible to make a distinction between three types of regularities that may be found in human conduct. First, humans have intrinsic properties. They have a body, which subsumes them to physical and physiological regularities. One clear example of this is that humans have to eat to stay alive. Further, humans are characterized by certain psychological regularities. They have certain memory capacities, a certain learning speed and inborn instincts. Such regularities are only to a very limited degree malleable by humans. Second, humans build a social reality (Berger and Luckmann 1966; Giddens 1984; Searle 1995). They turn pieces of paper into money and driving harder than 120 kilometers an hour into an offence. That is, they assign a function or meaning to 'brute facts of nature' (Searle 1995). Without humans these functions would be absent. Moreover, humans have to know these functions to retain them (Giddens 1984). These cultural rules are the second type of regularity we can find. In the history of social theory, the exact location of the dividing line between these social rules and psychological and physiological regularities has been subject to many disputes. It has been framed as the nature – nurture distinction. For example, Mead (1961) claimed that the phenomenon of puberty is not determined by nature but is the result of social rules (nurture). Third, social regularities exist that are neither 'brute facts' nor social rules, but depend on both of them. In chapter one I wrote that Tushman (1977) and others found that communication across different 'thought worlds' is more effective when it is done by boundary spanners, who are able to translate these thought worlds. This is not by itself a social rule. Humans cannot choose to change this regularity. Nevertheless, this regularity depends upon social rules. It presupposes that people have developed cultural systems that are understood by some of them. Furthermore, the regularity described by Tushman depends upon the brute facts of nature, such as the acoustic properties of air.

In this research I acknowledged the fact that the study of social reality requires an interpretative stance by taking an ethnographic approach. Ethnography enables the discovery of social rules. But I did not limit myself to the search for such social rules. I also searched for regularities that are not created by humans, but nevertheless depend upon them. The first type of regularities described above, concerning physical, physiological and psychological characteristics of humans, fell outside the scope of this project.

2.3. Empirical research

2.3.1. Empirical focus

The empirical research underlying this thesis was performed in two field studies: one at a research group of Philips Research Laboratories and one at a research group of Shell Global Solutions. The context of those field studies will be described in detail in chapter three. The choice for two field studies was based primarily on considerations about internal validity. To be able to do research as intensive as I considered necessary, practical limitations determined that I could do only one or two field studies. I choose to study two research groups that differed in the content of their research but were comparable in the type of innovative activities. By studying two groups, a wider range of interactions might be found. That would increase the completeness of the findings. On the other hand, when no big differences would exist, it would be plausible that the findings hold for more than these two groups.

Out of the many research and development groups at Philips and Shell I choose two quite fundamental research groups. In the previous chapter I reviewed studies indicating that the information processing requirements for different R&D tasks differ. For example, research projects depend more upon communication with other researchers, both inside and outside their own organization. Development projects depend more upon communication with other organizational functions, such as marketing and production. Knowledge-oriented communication is more important in research and coordination-oriented communication more important in development (Allen 1986). Another difference is that the output of research is predominantly knowledge and information. The output of development and engineering consists more of technical artifacts (Allen 1977). Finally, in research it is important that communication is distributed evenly among individuals. But in development and technical service projects, extra-group communication is preferably channeled through boundary spanners. Given these differences in information processing between R&D tasks, it seems wise to focus on one type of R&D task. I choose research since internal, knowledge-oriented communication is most important in research Furthermore, I was personally more interested in exploratory research.

I limited my study of technical communication to communication with other members of the laboratory. Communication with outsiders has been excluded to a large extent, as has communication with other functional areas, such as marketing and manufacturing. Communication with external parties is characterized by different mechanisms (Collins 1974; Faulkner and Senker 1995). As noted above, communication with other functional areas plays a less important role for researchers (Allen et al. 1980). Furthermore, I limited myself to the study of interpersonal communication – the use of literature was left out of consideration.

2.3.2. Data-collection

Past research has used a variety of instruments for collecting data on knowledge processes and technical communication. These include the use of questionnaires (e.g., Szulanski 1996), diaries (e.g., Allen 1977), interviews (e.g., Andrews and Delahaye 2000), observation (e.g., Orr 1990), documentation (Baum and Ingram 1998), experiments (e.g., Okhuyzen and Eisenhardt 2002) and simulation (e.g., March 1991; Hutchins 1991a). I choose for an ethnographic research strategy. This strategy is predominantly based on observations and interviews. The aim of this research, opening the black box of knowledge sharing, required a close analysis of the phenomenon. Cognitive anthropologists and sociologists of science have shown that, in order to understand the intricacies of technical communication, it is necessary to study it in its social, physical and work context (see section 1.5). Furthermore, taking interviews as the only source of data would be too limited. Subjects are not completely transparent to themselves. Their words may differ from their deeds. One should observe the process as closely as possible, in its natural context.

An ethnographic researcher participates in a community, and tries to learn something about that community by participating and using a range of different research techniques (Hammersley and Atkinson 1983). By studying a group from within, a researcher is enabled to take an interpretative stance. Ethnography is sometimes redescribed as participant observation. Participant observation can range from non-participation to complete participation (Spradley 1980: 59). This study lies between those extremes. Placed on this continuum, it is a case of passive participation. In passive participation the researcher is at the site of study but does not participate in the actions of the community members. Spradley (1980) cites open-heart surgery and professional ballet as examples of contexts in which it is extremely difficult to participate fully (at least, when one is not educated in such a profession). Likewise, it was impossible for me to participate as a full group member in the activities of the researchers at Philips and Shell. Participation was limited to lunch, social activities and very simple assisting tasks.

During the field studies, three basic types of data-collection techniques were used: interviews, observations and the gathering of documents. Interviews were used in the first weeks of both field studies to get to know the group members, their relations and their activities. In both groups, I spoke most of the research scientists, research engineers, apprentices and group leaders. These familiarizing interviews were held in the natural context of those interviewed: their rooms and laboratories. The interviews began with a short introduction of my study. The interviews were unstructured, but contained at least the following questions:

- How long do you work already within this group?
- What project(s) do you work on currently?
- With whom do you cooperate?
- Who will use the results?

Most of the subjects were very willing to talk about their research, to show results and to talk about the organization they were part of. Since these interviews were meant to get to know the group members, I followed them in the topics they brought up. Due to that, some interviews focused on the members' research questions, activities and results. Other interviews centered on organizational matters. The interviews lasted between half an hour and an hour. The factual information derived from these interviews aided in the understanding of interactions that I observed later. But it was not only the factual information that was important. Another important goal of these interviews was to build mutual trust, negotiate access and to let the group members get used to me. The interviews also yielded information about who to study in more detail in later parts of the field studies. These introductory interviews were not tape-recorded, since I feared that that might interfere with the process of building trust.

After six weeks at each of the research sites, I choose to follow a small number of group members more closely. There were several reasons to focus on a limited set of members. First, it is only possible to observe one interaction at a time. That means that only a limited number of interactions can be studied in depth. Second, the interpretation of an interaction is enhanced by knowledge of its context. Knowledge about research projects was very hard to master. Therefore it would have been inefficient to try to learn something about everyone's research. Third, centering on a few researchers enhanced the development of mutual trust. In the first field study, three group members were followed closely and one was followed to a lesser degree. In the second field study, one was followed closely and two were followed less intensively. These researchers were selected with an eye on variety on a number of dimensions.[9] Among the seven persons were five research scientists and two research engineers. Some of them were more theoretically oriented, some more experimentally oriented. Three out of the seven persons shadowed worked less than two years at the research laboratory and two more than fifteen years. Some of the projects the researchers worked on were in their early stages. Other projects were already going on for some years. Though it was not at all clear whether these differences would be theoretically relevant, taking care of this variety was seen as a way of assuring enough

[9] In total, I have asked nine persons. Two of them did not want to participate.

variety in the interactions studied. Furthermore, practical issues played a role in the selection of subjects. Would he (all were men) like to participate in the research? Can I get along with him? Is there a roommate who disapproves it?

I followed each of these persons between three and eight days. This meant that I stayed with them in their rooms as much as possible and followed them as a shadow wherever they went. I joined them in formal meetings, informal hall-talk, at lunch and listened to their telephone conversations. By following these researchers, I could observe an unselected range of interactions. This is not completely in line with the prescriptions of the grounded theory approach. The grounded theory approach calls for theoretical sampling, consciously selecting cases guided by theoretical considerations (Glaser 1978). However, this lack of selectivity was beneficial for later quantitative analyses. For many of the meetings the shadowed subjects attended, access had to be negotiated for me. Most people agreed to have me attend the meeting after they were told that I had signed a confidentiality agreement. I tape-recorded an important share of the conversations and meetings. This was not feasible in many other occasions. For example, I felt that I could not tape-record accidental meetings in the corridor. Asking both persons for permission to tape-record these short conversations would probably change their course. I took notes of these other conversations and meetings. Before and after meetings I asked the person that I shadowed questions about the purpose of the meeting, asked for clarification of the content and about the results of the meeting. I asked the researchers also about other recent interactions. In the first field study these interviews were unstructured. In the second field study questions were steered by the codes-in-development. Whenever possible I also spoke with the interlocutors of the shadowed researchers. Some of these ongoing interviews were tape-recorded. I took notes of the others. I transcribed most of the tape-recorded conversations and interviews.[10]

While analyzing transcriptions of conversations it sometimes turned out to be difficult to interpret what had happened in them, even when aided by the explanatory information received before and after the conversations. Therefore I choose to discuss some of the transcripts with the researchers. While listening to the tapes and reading the transcripts together, I asked questions for clarification. Why did you say that? What do you think of that answer? Was that remark useful for you? In what way? Cicourel (1990) and Johnson and Briggs (1994) advocate a similar approach. Johnson and Briggs call this a type of 'retrospective verbal protocol'. Such discussions proved to be a rich source of data.

[10] Due to confidentiality of most of the content of the interactions, I am limited in quoting extensively and literally from transcripts.

In addition to interviews and observations I also studied documents and intranet resources. These included descriptions of the group's research, laboratory structure and procedures. I read some internal reports and journal articles written by the group members as well. These documents and intranet resources were especially valuable for gaining insight in the context of the interactions (see also chapter three). I further collected some e-mails, both general e-mails sent to each group member (including myself) and e-mails sent between researchers. The combination of the different data collection techniques resulted in a little less than a thousand pages and more than thirty tapes. In these data around 250 communication episodes were discerned and labeled with a number (e.g., E26).

This ethnographic research approach made me a part of the social system, though a strange part. In both research groups I had my own desk and computer. I had lunch with group members, joined conversations, meetings, presentations and social occasions. Some of the group members expressed much interest in my research and interfered with it, like they do with colleagues. Questions were asked about my methods of research. Group members gave suggestions regarding my research design and criticized some of the choices made. But I remained an observer, a relative outsider. At some occasions I felt superfluous, like a fifth wheel under a car. But the field studies gave me the experience of seeing highly interesting research-in-action as well.

2.4. Analysis

2.4.1. Coding procedures

In the last section I described the ways in which I collected data during the field studies. In this section I will explain how these data were analyzed. The grounded theory approach employs three central procedures for analyzing data: open coding, theoretical coding and selective coding. I will discuss these three procedures subsequently. These discussions are based on Glaser (1978; 1992) and Strauss and Corbin (1990).

OPEN CODING

After (parts of) data collection have been done, a qualitative researcher is faced with the slightly discouraging view of a huge pile of paper with interview transcriptions and observations that need to be analyzed. One way to deal with this pile of data is to stare through one's eyelashes, scan the data and come to conclusions intuitively. Another approach is coding. Coding is attaching a label to a piece of data. By coding, some properties expressed in the data are summarized into a single concept. This enables the systematic comparison of data and reduces the cognitive demand placed upon us. Sometimes coding can be done with a set of existing concepts. The grounded theory approach is particularly useful when such a set is not yet available. The grounded theory approach starts with open coding. In open coding, codes are developed during the coding process. Reading a piece of data the researcher is supposed to ask himself: What is this piece of data about? What does this piece of data tell me? What is this an instance of? An answer to such a question can be captured in a code. That code may be an existing word or concept or a newly created one. It is also possible to use expressions present in the data itself (e.g., expressions used by interviewees). That is called 'in vivo coding' (Glaser 1978). Most important is that the codes are incited by the data and not by a preconceived set of codes. Codes should suit the data, be clear to the coder and be considered (potentially) relevant for the research problem at hand.

A strategic question with regard to open coding is the size of the fragments to be coded. It is possible to code sentences, larger fragments or complete documents. The grounded theory approach considers all of these options legitimate. However, Glaser and Strauss express a preference for sentence-by-sentence coding. This stimulates close reading and prevents overlooking relevant phenomena. Of course, which option is favorable depends on the units of research too. In this research, I choose the default option to code sentence-by-sentence, but coded larger parts as well.

Open coding thrives on the comparison of episodes. Characteristics of interactions become clearer if these interactions are compared with others. Comparing them shows differences and similarities and stimulates to put these into words. The process of open coding resulted in over one hundred codes in this research. These codes evolve over time. Like comparing data supports the creation of codes, the comparison of codes helps to sharpen them. During the process of coding it is common to find that two codes show important overlap. In such a case I turned back to the associated fragments and compared these sets of fragments again. Based on that comparison I choose to merge those two codes or define them more distinctly. In some cases I experienced that too diverse fragments were coded with the same code. In those cases the remedy was also to compare all the fragments subsumed under the code again and to divide them into different codes. Another common problem relates to the relevance of codes. Since this research did not start with detailed research questions, it was not immediately obvious which codes were relevant for further theory development and which not. In those cases I followed a liberal course and kept codes 'alive' until their irrelevance for the integration of findings was established.

A second step in open coding is the development of categories of codes. Some codes share certain characteristics and can be subsumed under higher order categories. These categories are also concepts, but of a more abstract nature. Such a categorization is the first step toward a theoretical integration of findings.

THEORETICAL CODING

The second analytical procedure of the grounded theory approach is theoretical coding. A theory consists of concepts and relationships between those concepts. Concepts are developed in open coding. Theoretical coding is oriented toward the discovery of relationships between concepts. Theoretical coding consists of putting relationships into words. These relationships can take many forms. A causal relationship is only one of them. One concept may also be a property of another, be a prerequisite for another, be followed in time by or be part of the context of another. Glaser (1978) distinguishes 18 families of types or relations.

Theoretical coding should be grounded in data as well. One should search the data to find indications for the existence of relationships. As Glaser (1978; 1992) argues, these will be found. Human interaction is not chaotic, but patterned. Interviewees themselves may indicate relationships. Also, the coder may see a certain relation between two codes. I used matrices to enhance this. In both cases the theoretical relationship will be of a hypothetical nature. In theoretical coding one is always working inductively, generalizing from individual incidents to more general patterns.

Logically, theoretical coding follows open coding. Before one is able to draw relationships, one needs to have concepts. But in the practice of coding these processes will be done in parallel and iteratively. During open coding I stumbled upon possible relationships and described those in theoretical memos. Conversely, theoretical coding inspired open coding.

SELECTIVE CODING

The first field study at the Nat.Lab. was followed by an intensive process of data processing and analysis. These analyses consisted predominantly of open coding and theoretical coding. I used Atlas.ti as a supporting tool. Atlas.ti is a software package that is especially designed for qualitative, grounded theory analyses. After the first stage of analysis, the evolving findings were compared with existing literature. Weick (1989) describes four possible evaluations of initial findings: 'that's obvious', 'that's irrelevant', 'that's absurd' and 'that's interesting'. Weick advocates that those initial findings that yield the reaction 'that's interesting' when compared to the literature are the one's to focus upon. The comparison with the existing literature showed on the one hand that some of the initial findings were already addressed. These raised the reaction 'that's obvious'. On the other hand this comparison raised some 'that's interesting' reactions. Those particular findings were considered to be potential contributions to the literature. I have chosen to focus upon these latter parts of the initial findings, those that were most promising as potential contributions to existing literature. The details of this choice provided the background for selective coding.

The third procedure advocated by the grounded theory approach is selective coding. Selective coding is meant to elaborate concepts and relationships found during open coding and theoretical coding. Selective coding does not aim at the development of new concepts but at the crystallization of results. Selective coding presupposes that a researcher scans his data for not yet analyzed instances of a particular phenomenon or relationship. A researcher may also go back to the field to selectively gather new data. Having preliminary concepts and hypotheses enables to ask more specific questions in and about the empirical sites of research.

The grounded theory approach pleas for an integration of data-collection and data-analysis. Only during coding it becomes clear what the research will precisely be about. Likewise, I could ask questions much more specifically in the second field study. I used a checklist to make sure that I gathered data on all relevant issues concerning the interactions. The process of selective coding, and the grounded theory analyses in general, can be stopped when concepts and relations are 'saturated', i.e., when additional collection and analysis of data do not lead to new insights any more.

2.4.2. Additional quantitative analyses

The qualitative analyses resulted in three main concepts (which are described in chapters four and six). Each of them was built up from underlying codes. Theoretical coding yielded ideas about relationships between those codes. These relationships have been further explored by quantitative analyses. A large set of interactions was coded on all their relevant aspects. This is explained in more detail in Appendix 5. Interactions that were not completely described were left out of further analyses. The quantitative analyses served primarily a qualitative goal. Coding a large number of interactions on all relevant dimensions, forced me to sharpen codes. Further, the quantitative analyses added insight about relationships. The quantitative analyses should not be conceived as independent tests of pre-formulated hypotheses. The qualitative ideas and the quantitative analyses are largely based upon the same material. The quantitative analyses were more part of theory building than theory testing. Nevertheless, they provided support for the relationships reported. These quantitative results will play a large role in the description of the findings of the empirical research.

2.4.3. Quality criteria

Traditional quality criteria for research are controllability, validity and reliability (Swanborn 1996). These criteria are tightly related to the epistemological criteria of justification and truth. In this section I will evaluate to what degree this research meets these criteria. Although qualitative research in general is less controllable than quantitative research, the grounded theory approach is a relatively controllable approach. When the procedures of open coding, theoretical coding and selective coding are followed, a researcher is able to trace back his findings to the original data. This is further enhanced by my use of the software package Atlas.ti. This software is designed to support grounded theory analyses. Furthermore, the quantitative analyses are controllable.

The reliability of a study is influenced by the research instruments used, the timing of the study, the subjects chosen and the researcher(s) carrying out the study (Swanborn 1996). Reliability with regard to research instruments was assured by using different data-sources: interviews, observations, post-hoc discussions and documents. Ethnographic research typically supports triangulation by using different data sources (Hammersley and Atkinson 1983). The influence of timing on the results has been restricted by observing for several months in both field studies. A third possible threat to reliability lies in the subjects that are chosen. I employed objective grounds to choose persons that I wanted to shadow (type of project, years of experience), but subjective grounds as well (could I get along with them?). This may have introduced a selection bias (Cook and Campbell 1979: 53). Maybe the persons that I have chosen were somewhat more sociable than others. But I belief that on average they did not communicate significantly more or differently than other group members. Therefore I do not think that the choice for particular researchers influenced the results in an undesirable way.

Most critical was the influence of myself as the researcher. During the field studies, my presence has influenced communication processes, most strongly by participating in conversations (for example at lunch). But also my mere presence, and the presence of a tape-recorder, may have changed the course of a conversation. However, I did not have the impression that this influenced the findings of this study. The researchers who were shadowed acknowledged this. They told afterwards that they did not change their communicative habits when I was present. Researchers can also be expected to influence the qualitative analyses they perform. Two researchers, starting from the same data and questions, will deliver different results, even when following the grounded theory approach. Different researchers may notice different phenomena. This is not an insurmountable problem. Grounded theory analyses are oriented at the development of theory, not at the testing thereof. Nevertheless, given a certain direction of theory development, results should become more independent of the researcher. The procedures of the grounded theory approach presumably yield more researcher-independent results than intuitive analyses and armchair theorizing.

To test and improve the researcher-independence of results, another researcher has coded a limited set of instances of technical communication at two moments in time. At the final stage of the qualitative analysis we both coded a set of 25 (parts of) episodes. We compared our codes and discussed differences. Many differences turned out to be caused by ambiguities in the description of codes. I adapted these descriptions accordingly. Some other codes showed overlaps. These codes were altered or merged. In some other cases the coding by the other researcher seemed to be more appropriate and I changed my coding of that particular episode. Another important problem was that some of the data themselves were not completely clear. I could use implicit knowledge about the subjects, the interactions and their context as well, but the other coder lacked the experience of having observed the interactions. This first check of the intercoder reliability served mainly a qualitative goal: improving the quality of results. Another check of the intercoder reliability was done after I coded all episodes used in the quantitative analyses. This time the second researcher coded 24 parts of interactions. Comparing our results in a quantitative way was complicated by the fact that there was no fixed number of codes to be attached to a part of an interaction. When the codes of the person who used the smallest number of codes were taken as a reference point, 63 percent of codes were similar (108 out of 171). As will be explained in chapters four and six, this study yielded three categories of codes. Two of them consisted of over twenty codes each. The chance of coding different was therefore much higher than in the case of a choice between a small number of codes. This is one explanation for the less than optimal intercoder agreement. Another major explanation is the lack of background knowledge of the second coder and the nature of the data. Data were collected for qualitative analysis. Only in the last phase of the field studies data were gathered systematically about all of the aspects that codes referred to. In some cases data were clearly lacking – these cases were abandoned from the quantitative analyses. In other cases data were ambiguous. For qualitative analysis this is no big problem. Glaser (1978: 56) states that a researcher *"… may even code for what is not obviously stated"*. Theory development is about finding conceptual categories and not about yielding fully correct descriptions of individual phenomena (Glaser and Strauss 1967). However, that logic of theory development conflicts with the conditions for a quantitative analysis.

Two relevant types of validity are internal validity and external validity (Cook and Campbell 1979; Swanborn 1996). Internal validity refers to the justification of the relationships identified. External validity refers to the degree to which findings can be generalized to other sites and populations. In this study internal validity was prioritized above external validity. Generating concepts and formulating relationships that are accurate for these particular organizations was prioritized above testing validity for all research organizations. The main reason to do so, is that the building of theory logically precedes the testing of theory. Concerning internal validity, it should be noted that it presupposes reliability. The above mentioned (possible) threats to reliability were also threats to internal validity. On the other hand, the study was designed to serve internal validity: the relevant phenomena have been studied meticulously, in their original context. In ethnographic research, internal validity can be tested by member checks (Swanborn 1996). A member check is an evaluation of the findings by members of the community studied. Preliminary results were presented in both research groups. Reactions to these presentations aided further analyses but did not point at serious flaws. Furthermore, observation notes were given to those researchers that I followed closely. The discussion of my observations with them enhanced my understanding and increased the study's validity. The downside of such an intensity of research, is that it constrains its extensiveness. The study did not result in comparable data from a large number of organizations. Only two, quite similar, research groups were studied. Between those groups I found no large differences. Concepts and relationships applied in both cases. This means that the findings are probably valid for other R&D groups engaged in exploratory research.

3.

THE FIELD STUDIES

In this chapter the two groups in which field-studies were carried out will be introduced. The first of the field studies was done within a part of Philips Research, the Materials Mechanics and Heat Transfer group. The data collection in this group was conducted between April and December 1999. The second field study was done within Oil and Gas Innovation Research, part of Shell Global Solutions. This group was studied between March and September 2001.

This chapter provides background information on these groups:

- *both groups are predominantly involved in research, and less in development and engineering*
- *their research is grounded in basic research, exemplified by the fact that members from both groups publish in scientific journals, and oriented toward the generation of technological options*
- *research is organized into relatively small projects; both groups are to a large extent themselves responsible for finding sponsors for these projects; the projects often contribute to larger projects of sponsors within the larger research, development and engineering organization or other business divisions*
- *although work in both groups is more driven by business-needs than in the past, the group leaders employ a supportive and not a command-and-control management style*
- *both groups employ a broad repertoire of communication genre's; this enhanced the chance of finding enough variety in the phenomena of interest in this study*
- *the main difference between these groups lies in their fields of research, but some other differences exist as well*

This chapter is meant to familiarize the reader with the context in which the research was conducted. It does not contribute directly to the development of theory, but enables judgements about the degree to which the results of this research can be generalized to other settings.

3.1. The Group Buijs

3.1.1. The Nat.Lab.

Royal Philips Electronics is one of the world's biggest electronics companies and Europe's largest, with sales of EUR 32.3 billion in 2001.[11] Its headquarter is currently located in Amsterdam (the Netherlands), but it's 184,000 employees are distributed over 60 countries. Philips' product divisions are active in the areas of lighting, consumer electronics, domestic appliances, components, semiconductors, and medical systems. Philips positions itself as a high-growth technology company, a company ensuring competitive advantage by generating innovative products and processes. A well-known example of Philips' innovations is the compact disc. Philips Research Eindhoven is Philips' largest research laboratory. It is more generally known as the Nat.Lab., an abbreviation of 'Natuurkundig Laboratorium' ('Physics Laboratory'). The Nat.Lab. is located in Eindhoven (the Netherlands), the birthplace of Philips. Besides the Nat.Lab., Philips Research consists of smaller laboratories in various other countries. The Nat.Lab. and the other laboratories of Philips research are responsible for research and development of technological options. Development laboratories of product divisions carry out the later phases of product development activities. The further development of production processes is the responsibility of the Center for Industrial Technology.

The Nat.Lab. was founded in 1914 to support the development and production of incandescent lamps by scientific research. It started by employing the physicist Gilles Holst, who led the Nat.Lab. until 1946 (Holst is the person on the left on the photograph at the cover of this thesis). The amount of employees increased quickly to 400 in the beginning of the 1930s. Over the years the range of topics researched has diversified dramatically. The Nat.Lab. has even been involved in agricultural research. Currently the Nat.Lab. delivers research results to all the product divisions mentioned above. It is not tied to any specific product group. Topics of research include for example information processing architectures, user-system interaction technology, physical chemistry, optics, storage and retrieval, displays, personal care and semiconductors. Nowadays the Nat.Lab. is one of the largest industrial research laboratories in the world, having a staff of about 1500 people. An important new development is the building of the Philips High Tech Campus on the grounds of the

[11] The description of Philips Research and the Materials Mechanics and Heat Transfer group is partly based on the "Living document Materials Mechanics and Heat Transfer", the "Nat.Lab. Quality Manual", the websites "www.philips.com" and "www.research.philips.com" and the history of the Nat.Lab. written by Boersma (2002).

Nat.Lab. The Philips High Tech Campus will also house the Center for Industrial Technology and development laboratories. According to the plans, in 2005 a significant part of Philips' wide diversity of R&D activities will be clustered at this single location. This bundling of R&D activities will result in a workforce of around 8,000 professionals.

In 1999, the work done at the Nat.Lab. was divided over eight sectors: 'information and software technology', 'materials and process technology', 'storage, measurement and control', 'devices', 'IC design', 'IC process research', 'electronic systems' and the internally oriented sector 'operations and engineering'. Each sector consists of a number of groups. The research described in this thesis was done within the group 'Materials Mechanics and Heat Transfer'. But within the Nat.Lab. groups are often not addressed by the name referring to the topics it works on. Groups are generally called after their group leader, partly because people are less variable than the research topics worked on. The 'Materials Mechanics and Heat Transfer' group was called the 'Group Buijs', after its current group leader Maarten Buijs. Currently (summer 2002) the Group Buijs is officially called 'Mechanics, Heat and Particle Optics'.

3.1.2. Activities of the Group Buijs

During my field study the Group Buijs employed around 27 members. Apart from the groupleader and two secretaries, these members can be divided in two groups: eight research engineers and sixteen researcher scientists.[12] One of the research scientists and two of the research engineers were women, the others men. The Nat.Lab. recruits new research scientists mainly directly from university. The majority of them have earned a Ph.D. degree in physics, chemistry, electrical engineering, mathematics or a related discipline. Only a few started working at the Nat.Lab. with only a M.Sc. title. During my field study one the members earned a Ph.D. degree on the basis of the work done at the Nat.Lab. (Slikkerveer 1999). Most of the research engineers have a higher technical or laboratory-oriented education. Usually new staff members are set to work on problems distinct from the topics of their theses or previous work. The majority of the researchers is destined to be transferred to a product division after five to eight years. Only a selected number of researchers stays at the Nat.Lab. to become a senior researcher.

The expertise of the Group Buijs lies in the areas of solid mechanics, fluid mechanics and thermal physics. All the activities of the group use one or more of these basic capabilities, or derived capabilities such as rheology, thermomechanics and heat and

[12] In this thesis I will use the term 'researcher' to refer both to research scientists and research engineers.

mass transfer. In 1999 the work of the Group Buijs was divided into six clusters: 'solid mechanics and tribology', 'plastic processing', 'thermal management', 'coating', 'printing' and 'home care'. These clusters have a cluster leader. Cluster members are expected to report about their work to their cluster leader, but the relationship between a cluster leader and a cluster member is not hierarchical. Research engineers, research scientists as well as cluster leaders are only hierarchically subordinated to their group leader. Within the group, 19 projects were running. These projects were staffed on average with about 1,5 man-year. Some of the researchers divide their time over more than one project. Each project has a project leader, to whom project members report about their activities for the project. The project leader reports to the owner of the project. The projects are often part of larger projects owned by another group or a product division. Within the Nat.Lab. a distinction is made between capability groups and system groups. System groups are owners of larger projects aimed at the development of new product concepts. Capability groups develop and maintain capabilities in order to support the development of the systems. The Group Buijs is predominantly a capability group. The Group Buijs works among others for storage technologies, displays and lighting. For example the coating-cluster, studying the behavior of liquids during coating processes, does research for the coating of television tubes and new generations of optical discs. Nevertheless, the Group Buijs was owner of some system-oriented projects too. Within the projects there is a lot of cooperation with different groups of the Nat.Lab.

Although research has become more business focused, researchers still experience a lot of freedom. One member of the Group Buijs stated that he preferred to work at the Nat.Lab. in stead of working at a university because of the opportunities it offers to build up own research facilities. An institutionalized expression of freedom in research is the concept of 'Friday afternoon experiments'. People are encouraged to spend some of their time, about half a day a week, on topics not immediately related to their day-to-day work. This is seen as fertile way of generating options for new research projects. Paul[13] describes one of the examples of this type of freedom. In the biweekly group work meeting ('GWO') he tells that he had an argument with colleagues about the question whether it would be possible to make an ordinary transparency with the powder blasting technique he and his colleagues were working on. He argued that it should be possible, but his colleagues denied. So he tried to do it, he succeeded, and at the group work meeting he put the powder blasted transparency in the available projector and proudly showed the result to his group. This little example is typical for the sheer pleasure staff members of the Nat.Lab. can experience in the solving of technical or scientific problems in relative freedom.

[13] Names have been changed in order to protect anonymity.

3.1.3. Research management at the Nat.Lab.

Philips Research describes its mission as generating options for successful industrial innovations, taking care of timely transfer of technical results to product divisions, initiating new businesses within the scope of Philips and helping to establish a strong patent position. The Nat.Lab. was based on the idea that basic research pays. Research yields profitable technological options and patents. To establish those options, the Nat.Lab. has its roots in fundamental scientific research. Soon after its start, the Nat.Lab. started to grow an academic culture. Researchers of the Nat.Lab. published widely in international journals, the Nat.Lab. built up an in-house library and scientists from universities were invited to give colloquia. In the 1920s a wide range of prominent scholars, including Ehrenfest, Einstein, and Pauli gave presentations (Boersma 2002). Researchers of the Nat.Lab. have always been encouraged to write articles in academic journals, to present papers and posters at international conferences and to collaborate with universities. This has several goals. First by publishing and presenting at conferences Nat.Lab. researchers show themselves as interesting partners for researchers from academia and other organizations. Second, it is a way to make the Nat.Lab. an interesting employer for future researchers (Casimir 1983: 273).

However, business interests and basic research are not always easy allies. Business interests are associated with profitability, marketable products, a short-term orientation, budgets and tight project management. Too much business orientation might result in losing the basis for radically new innovations. Basic research is associated with a long-term orientation, freedom, creativity, uncertainty, stubbornness, contacts with the outside world and reflection. The pitfall of focusing too much on free research is that it might result in brilliant ideas, but not in commercially viable products. Over the years the Nat.Lab. has undergone various developments and changes in organizational structure and strategy, implying redefinitions of the relationship between business interests and free basic research. Casimir, leader of the Nat.Lab. between 1946 and 1970 and an eminent physicist, summarized the ideas on research management of his predecessor Holst in ten commandments (Casimir 1983: 237).

> *1 Engage competent scientists, if possible young ones, yet with academic research experience.*
> *2. Do not pay too much attention to the details of their previous experience.*
> *3. Give them a good deal of freedom and give a good deal of leeway to their particular preferences.*
> *4. Let them publish and take part in international scientific activities.*

5. Steer a middle course between individualism and strict regimentation; base authority on real competence; in case of doubt prefer anarchy.
6. Do not split up a laboratory according to different disciplines, but create multi-disciplinary teams.
7. Give the research laboratory independence in choice of subjects, but see to it that leaders and staff are thoroughly aware of their responsibility for the future of the company.
8. Do not run the research laboratory on budgets per project and never allow product divisions budgetary control over research projects.
9. Encourage transfer of competent senior people from the research laboratory to the development laboratories of product divisions.
10. In choosing research projects, be guided not only by market possibilities but also by the state of development of academic science.

A substantial number of these commandments are still followed, as section 3.1.2 illustrates. However, around 1990 an influential reorganization has taken place that rejected or amended some other commandments. At the end of the 1980s Philips decided that business interests and freedom of research were out of balance, to the cost of the former. Nowadays some older staff members describe that former situation with a melancholic look in their eyes as a 'university without students'. But at the end of the 1980s it was felt that a more market-oriented strategy was necessary. Since this reorganization process, called Centurion, Philips expects from its research departments a more direct relation with product divisions. Formerly all research at the Nat.Lab. was financed as a whole. After Centurion 70 percent of all research projects has to be financed directly or indirectly by a product division. This is called 'contract research'. This implies that researchers have to write project proposals, try to get product divisions interested and negotiate with them about money, milestones and deliverables, and report about the project's progress. Although group leaders and higher management levels play an important role in this process too, researchers complain that they have to spend much time on arranging the sponsoring and the administrative side of project management. To avoid too much short-term orientation, 30 percent of research is sponsored from a general budget of the Philips Board of Management. This research is called 'company research'. It is meant for the development of promising ideas not yet oriented at a profitable application. Moreover, capability groups as the Group Buijs see it as their own responsibility to keep more long-term research goals in mind. For the development of basic technological capabilities, for which no sponsor might be found, they might look for so-called 'carriers'. A carrier is a specific contract research project that can be used to build up a part of the technological capability. A research group might use several of these sponsored carriers to reach a long-term goal. That not all long-term orientation has disappeared from research is shown by a research project of a member of another group with whom members of the Group Buijs closely cooperate. To gain knowledge about the deformation of polycarbonate over long periods of time, he kept samples for of it for seven years under controlled conditions. From his measurements he concluded that the volume shrinkage of the polycarbonate was much higher than what was to be expected from extrapolating short-term measurements (see Wimberger-Friedl and de Bruin 1996). It was remarked that such a long-term orientation is even difficult to realize at a university, with Ph.D. projects only lasting for four years.

3.1.4. Infrastructure and communication

The Group Buijs occupies two corridors in the largest building of the Nat.Lab. One of these corridors is at the first floor, the other at the third floor. Office rooms occupy one side of the corridors, rooms with experimental facilities the other side. Most of the researchers share a room with a colleague. The same is true for the experimental facilities: most of these laboratories are used by more than one person.

The Group Buijs uses a wide range of communication forms. People make appointments and talk to each other face to face. They use telephone and e-mail. They meet each other at coffee break, at lunch and at other social activities. Characteristic for a lunch at the Nat.Lab. is that it is followed by a kilometer long walk around the pond located at the terrain. Group members meet in project meetings, cluster meetings, the group work meeting (GWO) and the so-called Frits-colloquium. This colloquium is called after the group member who initiated it. It aims at keeping up competencies by inviting external and internal speakers. The GWO generally consists of two parts. First, there is a number of fixed agenda points, concerning changes in personnel, the larger organizational contexts, noticeable research results and some other topics. Second, there is a presentation by one of the group members. In addition to these colloquia within the Group Buijs, Nat.Lab. wide colloquium series exist. In the so-called Thursday Morning Lectures internal or external speakers give a lecture oriented at a general audience. Alongside the Thursday Morning Lectures, several series of more targeted colloquia exist. Among these are the Electronics Colloquium, the Information Technology Colloquium, the IC Colloquium, the Materials Colloquium and the Laboratory Techniques Colloquium.

Within the Nat.Lab. a range of outlets for the presentation of research results exists. Right from the start, Gilles Holst paid attention to the development of systems for the reporting of research (Boersma 2002). Philips Research has even published its own journals, *Philips Technical Review* (until 1989) and *Philips Journal of Research* (until 1998). Nowadays researchers write articles for international scientific journals, internal reports, technical notes and so-called ‘white cards’ (applications for a patent). Popular reports are written in the Nat.Lab. Journaal (with more general information about the Nat.Lab.) and the recently started journal Philips Research Password. Members of the group send each other their own manuscripts, either to inform or to get a review, and reports of conferences, notes of meetings, journals and articles. Furthermore, every researcher keeps his own laboratory notebook. The notebooks of all researchers from the past can be found in archives. Within the Nat.Lab. an intranet is being used, called the Nat.Lab. Wide Web. For instance, information about manuscripts written by members of the Nat.Lab. can be found here. Within the Nat.Lab. a wide range of courses is offered on technical and organizational topics. And, of course, researchers stay in touch with external parties and internal clients.

An interesting feature of the Nat.Lab. is the existence of the 'Expert Consult' agency. This office is established around 1993 in order to aid people to find expertise they might need and avoid that wheels have to be reinvented. The office keeps a database in which the fields of expertise of all Nat.Lab. employees are described by a system of 25.000 key words. According to Munro, who runs this office, his own experience is crucial for the use of the database. He says that the difficulty lies in defining the right key words and knowing personality characteristics of the people suggested by the database. Although this service sounds useful, Munro was not satisfied with the level of use. Within the Group Buijs some said that they occasionally used Expert Consult. Others conceded that they did not know of its existence or that they did not need it: they claimed to be able to track the right persons themselves. Luke told the following story about Expert Consult. Coincidentally he was lunching at the same table as Munro, when he told about a certain problem he was working on. This had to do with Laplace transforms. Munro offered that he would take a look in his database to identify the expert who could help him with that problem. Luke said that this was not necessary. Nevertheless Munro called up in the afternoon saying that he had searched in his database. Munro said: "*I can't help you. I have found that you yourself are the expert*".

3.2. OGIR

3.2.1. Organizational background

The second field study has been carried out at Oil and Gas Innovation Research (OGIR), a business group within Shell Global Solutions International.[14] Shell Global Solutions is part of the Royal Dutch / Shell Group. The Royal Dutch / Shell Group

[14] The description of Shell and OGIR is partly based on the document "Updated OGIR's working methodology", material found at the website "www.shell.com" and the intranet-site "sww-dev.thornton.shell.uk/ogir" and several brochures.

consists of a very large number of businesses. Most of them are part of five core businesses: Exploration and Production, Oil Products, Chemicals, Gas and Power and Renewables. Although the general public regards Shell as an oil company, it says of itself that it is 'primarily in the energy business'. This is exemplified by Shell's growing focus on renewable sources of energy. Shell Global Solutions is part of Shell Oil Products and consists itself also of a large number of business groups. These business groups together employ about two thousand people. Shell Global Solutions provides services and technology for customers in a wide range of industries including: gas, refining, exploration and production of crude oil, chemicals, automotive, motor-sport and many others. The businesses within Shell Global Solutions have traditionally been part of and worked for the Royal Dutch/Shell Group. Although other Shell businesses are still their most important customers, more and more work is being done for customers outside of the Shell group.

Although Shell currently makes an enormous amount of money by the exploration, production and marketing of fossil fuels, it shares the growing concern about the environmental effects of the use of these fuels. Within Shell, three partly intertwined scenarios are identified with regard to the future of the energy market. First, the hydrocarbon based energy market is expected to become more constrained with respect to supply, emissions and products. Another scenario is the rise of the hydrogen economy, in which hydrogen is the prime energy carrier. A third scenario is the development of a truly sustainable energy market, in which 'the needs of the present are met, without compromising the ability of future generations to meet their own needs'. Solar energy and biofuels might play a role in this. Shell does not want to wait and see things happen, but tries to contribute to the enabling this sustainable future.

OGIR wants to play a leading role in the exploration of pathways that enable the shift from the current oil and gas businesses to a more sustainable future. OGIR describes its mission as contributing to sustainable development in the areas of energy and mobility by generating innovative technological options. In order to do so, OGIR conducts its own basic and exploratory research, uses external scientific research, invents and tests new technological concepts, and turns these, if possible, into prototypes. At that point in the development of a new technological option, work is taken over by OGIC, the Innovation Commercialization group. The exploratory and innovative nature of OGIRs work gives this business group a distinct character within Shell Global Solutions. The other business groups within Global Solutions mainly focus on improvements within existing technologies.

3.2.2. Activities of OGIR

In March 2001, the technical staff of OGIR consisted of about 35 people. Half of them are so-called 'staff members', comparable to research scientists at the Nat.Lab. Most of these staff-members have earned a Ph.D. in the field of chemistry, physics or a related discipline. One of them has a part-time assignment as professor at the Eindhoven University of Technology. The other half of the technical staff consists of research engineers, assisting one or more of the staff members. In addition to that, OGIR employs three managers, two secretaries and most of the time a couple of interns from universities and colleges. OGIR is divided into two sections, OGIR/1 and OGIR/2. Somewhat simplifying one might say that OGIR/1 deals with improvements within the fossil fuels based energy markets and that OGIR/2 works on the development of sustainable energy systems. However, there is no strong dividing line between the two sections. Members of both sections refer to themselves as 'OGIRians' and sometimes do not even know to which section another OGIRian belongs. Most of the data-collection has taken place within OGIR/2, though not exclusively.

The work that is carried out within OGIR is organized into projects. At the moment this research was carried out, about 20 projects were running. The projects include the following topics: the use of carbon-rich refinery streams as a binder material to replace cement; biofuels; hydrogen storage; basic catalysis research. Projects might be product oriented as well as process oriented. On average, projects are manned with a little less than two man-years. But, for the reason that one person might be working on more than one project, most projects were staffed with two ore more persons. One of them, generally one of the so-called staff members, is assigned the role of project leader. Projects either span the whole trajectory from fundamental research to the demonstration of a prototype, or focus on one of these or intermediary stages. Over the last years, there is a growing focus on scanning the environment and Shell for already existing ideas. This type of work, called 'watching television' by the members of OGIR, partly replaces conducting own research.

3.2.3. Management

The fact that OGIR is an independent business group means that they are responsible for balancing their incomes and expenditures. However, OGIR does not aim at making profit. The OGIR management is responsible for a business plan for OGIR. If the management team of Shell Global Solutions agrees upon this business plan, OGIR has the freedom to do its business within the agreed guidelines. For OGIR it means that project teams present their project plan to the sponsor, agree the price and the timing and then have to deliver in accordance with the agreements. There are several types of sponsors for OGIR. Shell businesses pay for the development of new technologies or products for their existing markets. Further, Shell Global Solutions pays for projects aimed at the exploitation of existing technologies for existing and new markets. Finally, Shell businesses, Shell Global Solutions and the corporate level pay for the exploration of new technologies for new markets, especially in sustainable energy and mobility and projects whose outcomes are too uncertain to be business sponsored. In the day-to-day practice of projects, activities related to acquisition require a lot of time. It often proves difficult to get money for a project of which the outcomes are inherently unsure. Potential sponsors might require an elaborated 'business case', that is difficult to provide in an early stage.

Although Shell Global Solutions is part of the Royal Dutch/Shell Group, and works mainly for Shell businesses, they also work for clients outside Shell, as long as this does not conflict with Shell interests. Due to the possible future strategic importance of much of the work within OGIR, this business group only works for Shell. Nevertheless, OGIR cooperates with a large amount of organizations outside Shell. There are cooperative relationships with several Dutch and foreign universities, governmental organizations and industrial companies. Interestingly, on the topic of hydrogen storage there is a joint project with a research group at Philips' Nat.Lab.

One general manager, and two section heads form the management of OGIR. These are mainly responsible for the management of resources, the creation of new projects, supporting projects and the development of a yearly business plan. To reduce the overload of more or less bureaucratic management tasks for the OGIR managers, many tasks are delegated to members of the technical staff. These include financial administration, information technologies, external communications and health, safety and environmental matters. In general, the management of OGIR tries to reduce bureaucracy as much as possible, and maintains a management style based on support and coaching.

3.2.4. Infrastructure and communication

The employees of OGIR are distributed over more than four buildings. However, most of them are working in one of these buildings, the 'New Laboratory'. The adjective 'new' should not be taken literally anymore, since this building was constructed in 1942. The members of OGIR are working in six corridors distributed over three floors. Both offices and laboratories are situated along these corridors. Most of the OGIR members have experimental facilities in more than one laboratory. Simultaneously, most of the laboratory rooms are used by more than one of the OGIR members. The fact that about one third of the members of OGIR is located in other buildings, is mainly due to the facts that the members in question have to work with equipment that is located within another building or have to cooperate intensively with people in other departments. These distributed members prefer their current location above an office in the New Laboratory, though some of them, and OGIR management, are aware of the disadvantages from a communication perspective.

Within OGIR and Shell Global Solutions a variety of communication genres is being used. In random order the following can be mentioned. In the first place interactions between one or more researchers. These interactions can take the form of project meetings, brainstorm sessions, hall talk, appointments, lunches and coffee breaks. These face-to-face interactions have been the prime focus of this research. In addition to face-to-face meetings, e-mail is intensively used as well as the telephone. I have not come across any instances of video-conferencing or other new communication media.

In the second place there are department wide and group wide communication fora. About once a month a department meeting is being held. Regularly this department meeting is accompanied by or substituted by a department lecture by a member of the OGIR staff. In addition to that, two times a year a so-called collective ambition workshop is being held in which all members of the OGIR department discuss OGIRs strategy and try to achieve consensus upon it (this initiative is based on ideas of Weggeman (1995)). In the spring of 2001 the initiative was launched to hold lunch meetings for all the staff members of OGIR, in which ongoing work from one of the running projects is being discussed. Occasionally the two sections, OGIR/1 and OGIR/2, organize section meetings. There are no formal cluster-meetings like they exist within the Nat.Lab. However, in the winter of 2000 / 2001, a group has been formed around the topic of reactor technology that has had a couple of meetings. Further, the group of people working on the so-called Fischer-Tropsch reaction, have a weekly lunch together.

In the third place there are communication forms that transcend the boundaries of OGIR. Reports are an example of this. Member of the technical staff occasionally write papers for scientific journals and conferences (see for example Kramer et al. 2001; Verbist et al. 1996; Kramer et al. 1993). There is also the possibility to write internal reports. This used to be part of normal practice, but over the last years the amount of internal reports written is diminished. The staff members attribute this to the fact that they do not get time and money for it. Another paper outlet is the Explorer. The Explorer is the newsletter of OGIR that is being distributed to around five hundred persons within Shell. It contains short descriptions of the projects of the technical staff. However, it is written for a more general audience and therefore these articles are not comparable to full technical reports. The OGIR website also contains some information on the running projects. This OGIR-website, launched in May 2001, contains also information on OGIRs style of working, OGIR members and their areas of expertise, upcoming colloquia and past scientific publications. The website is part of a larger intranet, called the Shell Wide Web. In addition to information on the various business groups, this intranet also offers online access to library services. OGIR also organizes colloquia that are open to all members of the SRTCA (Shell Research and Technology Center Amsterdam). For these colloquia external speakers are invited. Other business groups within Shell Global Solutions do not organize comparable meetings. Finally, one of the members of OGIR composes the Energy and Mobility Newsletter. He scans a worldwide range of sources on articles dealing with political, economical or technical aspects of energy and mobility. Abstracts of these articles and shortcuts to the full articles are distributed to about one hundred interested persons and published on the OGIR website.

3.3. Concluding remarks

These descriptions of the two research groups studied show that they have many things in common. This holds in the first place for the type of work being done. Using the classification described by Tushman (1978), Allen et al. (1980) and others, most of their work consists of applied research: 'work involving basic knowledge for the solution of a particular problem. The creation and evaluation of new concepts or components but not development for operational use' (Allen et al. 1980: 3). Some of the work involves more basic research. Development and technical service activities can also be found, but to a lesser degree. In general we can say that the work of both groups is best characterized by the term 'research' and not 'development' or 'engineering'.

The types of communication in place in both groups show much overlap as well. In terms of the work of Orlikowski and Yates (1994), we might say that they enact a comparable genre repertoire. Genres are socially recognized types of communicative actions, characterized by a certain purpose and a certain form. The typical example of a genre, according to Orlikowski and Yates, is the internal memo. A genre repertoire is the set of genres routinely enacted by a particular community (Orlikowski and Yates 1994; Yates et al. 1999). The genre repertoires of both the Group Buijs and OGIR encompassed presentations, project meetings, informal technical conversations, reports, competence lists etc. A difference is that within OGIR an equivalent of the cluster-meetings of the Group Buijs is lacking. Vice versa, the Group Buijs lacks something comparable to OGIRs collective ambition workshops.

Other similarities concern the characteristics of the workforce and the relationships with the outside scientific world. Of course there are differences as well. OGIRs position within Shell Global Solutions differs from the position of the Group Buijs within the Nat.Lab. Whereas several comparable research groups surround the Group Buijs, OGIR is the only group of its kind. This reveals itself in the type of cooperation with other groups, the lack of other organization wide colloquia, and a more complicated financing structure. This latter point is also related to the fact that OGIR is an independent business group while the Group Buijs is not (within the Nat.Lab. there are three business-group like ‘self-financing activities’, but these are exceptions to the general structure).

Many innovation management principles can be traced within both organizations. For example, OGIR recently implemented some ideas from the management literature, namely the game changer program (see Hamel 1999) and the collective ambition workshops (see Weggeman 1995). On the other hand, these research organizations have been ahead of the literature. In 1923, long before Allen (1977) wrote on the influence of architecture on technical communication, the Nat.Lab. moved into a new laboratory building that was purposefully designed to foster spontaneous contacts between researchers (Boersma 2002: 44). Further, both groups have since long developed structures and systems that would nowadays be characterized as knowledge management. The writing of reports, open communication, the Expert Consult office and of course the general focus on knowledge development can all be found as prescriptions in management literature. These examples indicate that research groups can learn from social scientific reflections, but that knowledge and innovation management can learn from actual research practices as well.

4.

MOVES AND EFFECTS

In this chapter the first part of the empirical research results will be presented. These results deal with the contributions of technical communication to industrial research practices and the ways in which these are accomplished. Three concepts take a central place in the results: moves, effects and origination mechanisms. Technical communication can be described as an iterative and interactive series of originations, moves and effects. This chapter concentrates on moves and effects. Contributions of this chapter are:

- *an introduction of the concepts of moves, effects and origination mechanisms, and their relationships*
- *a taxonomy of moves found in research-related communication; this taxonomy shows the heterogeneity of technical communication*
- *a comparison with earlier attempts to capture the content of technical communication in research, showing that these earlier taxonomies are too limited in scope*
- *a taxonomy of research-related effects of technical communication; this taxonomy shows the different ways in which technical communication can contribute to industrial research practices*
- *a distinction between direct contributions and indirect contributions; direct contributions are effects that are directly useful in the process of constructing and solving problems; indirect contributions are not directly useful, but may enable further communication and future recombinations of knowledge; these direct and indirect contributions are equally common*
- *the observation that moves are not necessary and sufficient causes of effects*

The taxonomies of moves and effects (together with the origination mechanisms to be discussed later) enable a detailed description of technical communication and its contribution to industrial research practices. They will be used in the theoretical chapter and the chapter on origination mechanisms.

4.1. Introduction

In my study of the contribution of technical communication to industrial research practices, I came across interactions like those depicted in vignettes below. All contribute to the work of those involved, but the exact contributions and the ways these are realized differ. One thing that immediately catched my eye when I was observing and analyzing instances of technical communication was that a great variety of actions are undertaken within communication. Frequently people speak of 'communication flows' or 'flows of information'. The word 'flow' might evoke the image of a relatively homogeneous flow of a liquid, like water in a river or blood in a vein. But technical communication is far from homogeneous. The boxes show the following communicative acts. In E26, Edward advises Richard to consult Henry about the construction of an experimental set-up; Henry rejects an initial proposal from Richard and subsequently proposes a new solution. In E206, group members tell stories that they consider nice to tell. Later on, Karl shows a piece of measuring equipment to his colleagues and tells about its options. His group members ask for further explanation. In E153 Andrew describes his activities, his research problems, theories that he uses and results he has produced. The other attendants refer him to earlier work of others and pose critical questions. Other interactions show different communicative acts. These acts contribute in heterogeneous ways to the practice of research.

Vignette A: E26
At the 10th of June, 1999, Edward visits his colleague and friend Richard. At this moment, I was staying in Richard's room. Richard tells Edward that he is busy with the creation of an experimental set-up to make some surface-phenomenon visible. This phenomenon is especially visible at the dew-point temperature. Richard says that he wants to have a heating-element in a closed box, in order to get the right temperature. Edward, who has been working longer within the group, says that Henry might help him. He says that Henry has done many temperature-sensitive experiments. "*He might even have such a box*", says Edward. The same day, Richard visits Henry. He explains his problem and his ideas for a solution. Henry initially rejects the proposal of Richard. In stead, he suggests to use a simple cup of ice to lower the temperature. Henry thought up this solution while reflecting on Richard's question. Afterwards, Richard tries this proposed solution, and it works (at least as a first start). He says to me: "*I went for something completely different. But they are so clever. I will ask him questions again. He is approachable. He is amazing, brilliant.*" Indeed, in the days and weeks following this interaction, Henry gets more involved in the project of Richard.

Vignette B: E206
During one of my first days at OGIR, I am having an interview with James. He tells that at 10.00 o'clock Robert and Karl offer coffee and pastry in corridor 11, to celebrate with the other group members that a new piece of measuring equipment has arrived. Drinking the coffee, remarkable stories about past research are told. One person tells about experiments a Ph.D.-student once did on nucleation. Because nucleation is a stochastic process, he had a hard time to get reproducible findings. James comments: "*Stochastic experiments yield a stochastic dissertation*". After eating the pastry, Karl shows the instrument in his laboratory. He explains its options, its intended use and tells proudly that this instrument is unique in the world. He shows some graphics on a computer screen representing the first experiments done with the instrument. The group members listen interestedly, asking sometimes for more detailed information, though most of them will never have to use the instrument.

Vignette C: E153 and E175
In meetings of the 'Miniaturization and Integration in Polymers' cluster, researchers present research findings to each other. This cluster consists of four researchers from the Group Buijs and a number of researchers from other groups. This particular meeting lasts from 14.00 to 17.00. It starts with a presentation by one of the researchers from another group. In the second half of the meeting Andrew presents his research: "*Uh ... I think that most people know what the project is about, but I will start broadly. (...) It is about the project polymer-metal ... and the aim is to improve properties of the boundary between polymer and metal. (...) I always start with this sheet, because it shows how to split up the different factors involved. There are macroscopic effects, but there is also the microscopic-side. (...) Further, another aspect is of course the molecular aspect*" Andrew goes on to tell about different types of polymer-chains and relaxation-theory, his initial hypotheses and models, experiments and the way these experiments changed his beliefs. In the course of his presentation he gets interrupted more and more. For example, Frasier says: "*You could also solve that (particular) problem numerically (...). Etienne has done that once*". Joel reacts: "*Thomas has solved something similarly analytically*". "*But*", Frasier responds, "*both Etienne and Thomas have not yet incorporated the insights of Janeschitz-Kriegl*". After the meeting Frasier tells me that he wants to discuss some issues in more detail with Andrew. A few days later he expresses doubts to Andrew concerning the applicability of a theory used by him. Andrew assumes particular material properties, but Frasier doubts whether those properties hold when the material has fibers in it, as is the case in Andrew's project. The doubts expressed by Frasier spur Andrew to investigate the material characteristics. He decides to ask Pete, the expert on rheology, to execute some measurements to determine whether the actual rheological properties differ significantly from the assumed properties. The cluster-meeting and the latter conversation with Frasier, have yielded more questions for Andrew than he had before. But he did not consider that as a negative effect. Months later he told me that the meeting had been very productive to him.

Several other differences may be found between interactions like these. One other set of differences concerns the effects that these episodes have on the participants. In E26, Henry first learns something of the project and specific problem Richard is working on. In turn, Richard receives an idea to construct an experimental set-up and tries it the very same day. As a provisional set-up, the cup of ice works well. He keeps using it for several weeks. Furthermore, Richard has become lyrical about the capabilities of Henry. In the days and weeks following this interaction he consults Henry several times more. In the time I am in Richard's room, he gets to know more group members. He says: "*Once you start up building that (network of relationships, HB) ... the amount of knowledge that you can get!*" (NL 990622).[15] In E206, group members learn something about the presence and options of a new piece of measuring equipment, but most of them will never use it. Nevertheless, they share the excitement of those who have ordered it. Furthermore, by asking questions, they incite Karl to tell more. This is another effect communication may have. Finally, in E153 the attendants of the cluster meeting learn about the research of Andrew. This has no direct implications for their own research. But the comments of the others, yield new questions for Andrew and spur him to scrutinize some of his assumptions. These different effects are different ways in which technical communication can contribute to research practices.

Guided by the research goals of this study, one other difference between interactions like these attracted my attention. The interactions and their content are initiated in different ways. In E26, Edward visits Richard since he and Richard have a friendly relationship. Knowing about Richard's project, Edward suggests to consult Henry. Richard did not ask for such an advice, but accepts it gladly. When Richard goes to Henry, he asks explicitly after suggestions for his experimental set-up. Henry does not have a solution on the shelf, but thinks up a provisional solution: using a cup of ice. In E206, Karl does not have to think up a solution. He and his collaborator Robert have invited their group members, and Karl tells some of the things he knows about his new equipment. In E153 Andrew uses the familiar format of a cluster-meeting to present his own research. His intention is not to help the others. But the others combine what they learn about Andrew's project and their own background knowledge, and come up with criticisms and references to earlier work that they consider useful for Andrew.

The empirical part of this study has explored these three sets of differences between interactions. A large group of codes that emerged from the data-collection and

[15] The combination of characters between brackets refers to the field notes from which quotes are taken.

analyses along the lines of the grounded theory approach referred to specific communicative acts. I have subsumed these specific codes under a general category labeled 'moves'. These can be seen as the content of communication. A taxonomy of 29 different types of moves was constructed.

Another part of codes developed in open coding concerned effects of technical communication. Moves have effects. Like there is a diversity of moves, there is a diversity of effects. Examples are an increased belief in a solution, learning about the activities of a fellow-researcher and trying a suggested experiment. These effects are the locus of the contribution of technical communication to the practice of industrial research. Since I am interested in this contribution, the focus is on research-related effects. Technical communication may have other types of effects as well. For example, researchers may get bored or excited. These other types of effects were left out of consideration.

The second research problem stated in the first chapter concerned the ways in which the contribution of technical communication to industrial research is realized. One answer to that question is that the contribution of technical communication is accomplished by a set of moves. But we can also pose the question how these moves are realized. The examples discussed above show that there are different ways in which communication is realized. I will introduce the concept of origination mechanisms to describe these different ways. The concept of origination provides an explanation for the communication of a particular content, and not something else.

Moves, effects and origination mechanisms are the concepts developed to analyze the differences alluded to in the above examples. Taxonomies have been developed for each of them in order to conceptualize these differences. However, the empirical study went beyond merely conceptualizing differences. The examples indicate also that origination mechanisms, moves and effects may be interrelated. These relationships are represented in Figure 4.1. This is a simple model of the contribution of technical communication to the practice of industrial research. In addition to the central concepts, this model consists of four arrows. The first arrow goes from origination mechanisms to moves, expressing that moves are brought forward via a particular type of origination. Another arrow goes from moves to effects, indicating that effects are brought about by moves (in combination with other factors). Nevertheless, there is also an arrow going directly from origination mechanisms to effects. This means that the processes from which moves originate may also have direct effects. The reverse arrow going from effects to origination denotes that the effects of moves can in turn become input for interactions in general and moves in particular. The model is iterative in nature, like communication is often. In this and the following chapters flesh will be added to the skeleton of this model.

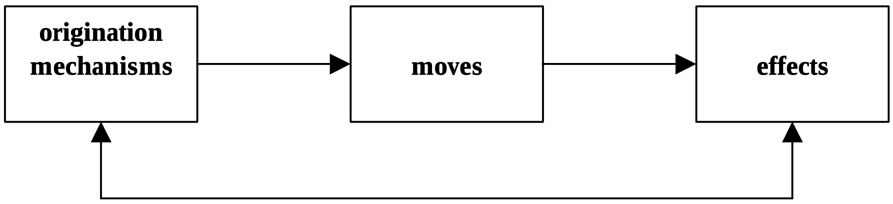

Figure 4.1: model of the contribution of technical communication to industrial research

I would like to emphasize that this model is a product of the empirical research. It is not a pre-specified conceptual model. It is the result of the grounded theory analyses. The elements are categories of codes that were constructed during open coding and selective coding. This holds as well for most of the types of moves, effects and originations. The relationships have been found by means of theoretical coding and quantitative analyses, as explained in chapter two and chapter six. Further, it should be noted that a model like this one is a partial abstraction. The focus is on the contribution of technical communication to the practice of industrial research. The model concerns the 'work' done in interactions. Many, many aspects might be discerned with regard to communication, interaction or knowledge sharing, and only some of them have turned up in this model. I do not intend to yield a 'complete' model of technical communication in this thesis.

In the remainder of this chapter I will present taxonomies of moves and effects that have been found in the two field studies. In the discussions following these overviews I will link these findings to existing literature. Origination mechanisms will be discussed in chapter six and associated knowledge processes in chapter seven.

4.2. Taxonomy of moves

In this section the different research-related moves that have been found within interactions are described. A move is a unit of communication in which a particular act is realized. The term 'move' is borrowed from Goffman (1981: 24) and Pentland (1992). A move is a meaningful unit of communication. Some moves are identical to single speech acts. But moves may also consist of several speech acts of the same type. Moreover, as we will see, moves can also have an extra-linguistic component. For these reasons the concept of move was preferred above that of speech acts – though my use of the term move is certainly influenced by speech act theory.

I have identified 29 types of research-related moves. Table 4.1 gives an overview of them and reports the number of episodes, out of a set of 227 episodes, in which each of them has appeared.[16] For the classification of a communicative act as a type of move, it does not matter whether it involves spoken words, written words, written support (such as white boards or overhead sheets) or graphical representations. I do not claim that my way of distinguishing moves is the only option or the best choice. Other taxonomies, more or less detailed, would have been possible. Nevertheless, I have tried to be exhaustive within the context of this classification. In this section the moves have been placed into groups. These groups are 'descriptions', 'proposals', 'evaluations', 'questions' and 'actions'. I will discuss these groups subsequently.

<u>*Descriptions*</u> - reporting about others (26) - describing own activities (52) - describing own knowledge (13) - describing own problem (26) - describing findings or theory (26) - describing earlier interaction (7) - describing experiment (12) - describing own results (45) - describing technology (15) <u>*Proposals*</u> - hypothesizing (21) - suggesting technical solution (23) - suggesting experiment (12) - suggesting new research (16) - warning (4) - instructing (17) - referring to person (7) - referring to literature or interactions (8)	<u>*Evaluations*</u> - giving arguments (37) - agreeing (22) - rejecting (19) - concluding (23) - redescribing and summarizing (7) <u>*Questions*</u> - asking a question (52) - questioning (7) - asking for help (9) <u>*Actions*</u> - showing (10) - handing over publications (3) - on the spot calculating or trying (8) - expressing observation (6)

Table 4.1: Taxonomy of research-related moves

[16] Details of the quantitative analyses can be found in Appendix 5.

Descriptions

REPORTING ABOUT OTHERS

This label refers to reports about other persons, groups and organizations. This might be about immediate colleagues, other members of the same organization, competitors or other external organizations. One might for example tell about current activities of others, about their plans for the future, their knowledge, the tools they use and their past successes, failures and stupidities. Especially these latter topics are favorites at lunch and coffee breaks.

DESCRIBING OWN ACTIVITIES

This move consists of a researcher telling about his own activities in the past, present and future. This may encompass telling about finished research, experiments carried out, topics he is currently working on, the way he approaches problems, the type of solutions he uses, the literature he reads, past successes and blunders, project structures and plans for the future. Describing own activities may occur in reports, in presentations and over lunch. In contrast with 'describing own problem' and other moves, this move has a more general nature and it is not used when problems, solutions or experiments are described in detail. Nevertheless, describing own activities might turn fluidly into one of those other types of moves.

DESCRIBING OWN KNOWLEDGE

This code is used when someone reports about his own knowledge, abilities or experience or the lack thereof. It refers to a meta-description of one's knowledge, not to telling things that can be classified as one's knowledge. It encompasses telling that you have not understood something, are in doubt of something or do not know something. It might be used as a substitute for a question. In E98 John said to Jack: *"I understood from Expert Consult that you are working on or have been working on the filtering of air in clean rooms."* This statement about his own understanding is an invitation for Jack to start telling about his activities.

DESCRIBING OWN PROBLEM

This code is used when a researcher gives a description of one of the problems he has. This might encompass describing details of the problem, its context, solutions that have been tried and the focus that has already been chosen. It might concern an overarching problem as well as a small sub-problem.

DESCRIBING FINDINGS OR THEORY

This move consists in describing theory or findings of others. This includes measurement data. An example can be found in E226 in which Richard describes the rate of corrosion of a material: "*That speed is about 0,5 millimeters a year*". Another example can be found in E210. In this episode, Michael gives a presentation about his study of well-to-wheel efficiencies. He uses the concept exergy, and describes the background and use of that theoretical perspective. This type of move has a description-like character. The content of what is said is not a proposal, is not called into question, and not judged, but stated as a matter of fact. It does not refer to the utterance of own research results.

DESCRIBING EARLIER INTERACTION

When a project member has missed a meeting, somebody else might tell what has been talked about in that meeting. Or someone describes an earlier communication episode because he has enjoyed it or got frustrated by it. This code includes passing on a message from someone else, describing visits to other institutions and mentioning assistance one has received from a colleague. When Rod stated that he wanted John to work with a certain type of software, John responded that he had heard from Cliff, who is an expert in the relevant field, that that piece of software is not very reliable. Mentioning an earlier advice might be used as an argument for one's point of view. It might also serve to express gratitude.

DESCRIBING EXPERIMENT

In E206 Karl describes the working of a new measuring instrument that arrived. In E13 Paul says to Richard (who wants to analyze photographs): "*What do you want to compare? For example it is possible to subtract pictures from each other. That is useful when there is a background you want to get rid of*". Moves like these were coded as 'describing experiment'. Describing an experiment might encompass a description of equipment, its intended use as well as a description of an experiment carried out.

DESCRIBING OWN RESULTS

This code refers to the description of the results of own research activities. This can be qualitative observations, quantitative measurements, models, simulations and more general conclusions. It includes presenting graphical illustrations of results. The description of results might be more or less detailed. The results may be hard searched for or occasionally stumbled upon. They may be satisfying or unwanted. Results may be reported formally or by telling stories on informal occasions.

DESCRIBING TECHNOLOGY

This move consists in a description of an existing product, process, material or other technological artifact. It may include describing the way a piece of technology works, its constituting elements and instructions for its use. The term technology also encompasses computer hardware and software.

Proposals

HYPOTHESIZING

This code refers to uttering a hypothesis with regard to the cause of a problem, the origin of a certain effect or a prediction about the value of a parameter. An example of it is found in E37, in which JL comes up with a hypothesis with regard to the cause of a coating deficiency that afflicts MB.

SUGGESTING TECHNICAL SOLUTION

Proposing a possible technical solution. This might be a solution for a process- or product-improvement. It might be a completely new idea, an existing idea, or an elaboration upon an existing idea. Suggestions range in strength from asking whether something would be possible to advising a solution. Characteristic for this type of move is that it is a proposal, which is not necessarily claimed valid or effective. A stronger move would be classified as 'instructing'.

SUGGESTING EXPERIMENT

This move consists of introducing or suggesting an experiment or suggesting a way to use an experiment. E226 provides an example of this type of move. Geoffrey said to Richard: "*A thousand-hours test has been carried out. You might compare your results with the results of that test*".

SUGGESTING NEW RESEARCH

This type of move refers to telling about a research idea one has for oneself or someone else. It might also involve a problem to work on or a proposal for a prioritizing of research problems. It does not require that one urges or instructs the other to work on that idea. Moreover, the introduction of a research idea does not presuppose that one considers it a good or bad idea.

WARNING

A warning is a move that tries to keep someone from a course of action. For example, in E269 James says to Andrew in reaction to his interpretation of a SEM-picture of a catalyst particle: "*Watch out with depending too much on the big grains you see.*"

INSTRUCTING

Instructing means telling someone to do something or how to do something. An instruction has a normative character. It may be interpreted as giving an order or giving a strong advice. Instructing goes beyond suggesting a possible solution. It consists of urging the other to use that solution (or experiment etc). An example is E6, in which the researcher Jason tells his engineer Rick not to try to get the best picture, what might cost a lot of time, but to strive for a satisfying picture. Another example is the following: "*You have to take care of it that the air really goes through the filter and not around the filter. That's really crucial*" (E98).

REFERRING TO PERSON

This move consists in advising someone to talk to someone else. Vignette A described E26, in which Richard tells his friend and colleague and friend Edward that he needs a heat source in one of his experimental set-ups. In response to this Edward tells Richard to go to Henry, because Henry has experience with heating problems. The person to whom is referred may in some cases even be oneself: "*If you have questions of that and that kind, you can come to me*" (E83).

REFERRING TO LITERATURE OR OTHER INTERACTIONS

Reading scientific and technological literature is sometimes called the cheapest form of research. Existing literature can be of great importance. For that reason researchers point each other occasionally at relevant literature. One might advice the other to read certain books or articles to get acquainted with a certain topic or tell about a new publication relevant to his current activities. This type of move also covers referring to other sources, such as the internet, and referring to upcoming interactions.

Evaluations

GIVING ARGUMENTS

This move refers to arguments that are uttered to support or undermine a possible solution or opinion. This includes giving factual evidence, pointing at strengths or weaknesses, advantages or disadvantages, presenting a complete line of reasoning, the explanation of the working of a technical solution to justify its use and presenting an example.

AGREEING

This code refers to expressing agreement regarding a technical solution, experiment, explanation, research program or whatever. It might refer to something immediately said before, but that is not necessary. It includes saying 'you're right', admitting an error, confirming an expressed hypothesis, calling a solution 'justified' or restating what has been said in other words to show agreement. It also includes conditional agreements. One may express agreement by spoken or written words, but also by the use of body language. In this research, however, not much attention has been paid to the use of body language.

REJECTING

This is the opposite of agreeing. This type of move consists of denying what someone else says or rejecting an expressed hypothesis. Such a rejection can be made more or less explicit. An expression of disagreement may also be shown by body language. A rejection need not be completely outspoken. This code also refers to expressions like 'I do not think that that is the case'. Agreeing and rejecting can be seen as the expression of belief or the lack thereof.

CONCLUDING

This move consists in someone uttering a conclusion that he has drawn. In contrast to agreeing or rejecting, which can also be seen as types of conclusions, moves labeled 'concluding' are not reactions to previously expressed suggestions, but set a step further. Concluding may be related to the interpretation of research results. To mention an example, in E56 Peter observes a broken disc in order to find the cause of the fact that it broke. Based on his observations he utters the conclusion that a little crack in the surface material caused the whole disc to break.

REDESCRIBING AND SUMMARIZING

This code refers to summing up what has been said before or conceptualizing it in a different way. One might think of a summary that is given at the end of a meeting, or notes that are made of a meeting and passed on to the other participants. Redescribing goes beyond merely repeating what has been said. It consists of giving an alternative conceptualization, putting something in other words. An example can be found in E98. After Jack introduced a technical solution, John says: *"Actually that is making a sort of miniature clean room"*. Redescribing and summarizing are viewed as one type of move because they are hard to distinguish. A redescription is a form of summarizing, and summarizing is a form of redescribing.

Questions

ASKING A QUESTION

This move encompasses asking all kinds of open and closed questions. These questions may concern activities, problems, possible solutions, theory, plans, earlier interactions, literature, etc. It also encompasses questions to test one's understanding *("You work with a layer of fifteen nanometers, don't you?")* and requests for explanations (*"Why do you say that?"*).

QUESTIONING

This type of move consists of asking a critical question or calling another one's claim by other means in question. An example of such a critical question was posed by JL in reaction to a presentation of measurements on optical discs: "*How do you know that the emission- and absorptionspectra are the same?*" (E1). One may also call results in question by uncovering dubitable assumptions: "*But you use one basic assumption: that the border conditions are everywhere the same, that there is one uniform border (...) It could be that in a place like this (points at a picture) the flows differ*" (E232). There is no sharp distinction between questioning and just asking a question. A neutral question might turn into questioning when someone is unable to produce a satisfying answer.

ASKING FOR HELP

Asking for help does not consist in asking for an answer to a specific question, but asking for support with regard to a certain problem or answer. Examples are asking to reflect upon a report written, asking for help with a piece of measuring equipment and asking to think about a certain problem.

Actions

SHOWING

Some moves consist of non-linguistic elements as well. These action-like moves are heavily situated. They presuppose, for example, a piece of measuring equipment, a product or a blackboard. One can only observe them when observing communication in its context. A prominent type of an action-like move is showing. This might involve showing equipment, prototypes, and examples of products or research material. It also includes the demonstration of the working of measurement equipment and the actions required to execute an experiment. It does not refer to the use of graphical illustrations for the descriptions of research results. Showing things and actions is especially relevant for the transfer of know-how, since know-how is often difficult to verbalize.

HANDING OVER PUBLICATIONS

Another type of an action-like move is handing over a publication to someone else. This includes handing over or sending one's own manuscripts.

ON THE SPOT CALCULATING OR TRYING

This code refers to real time working on a problem within the context of an interaction. An example is E15. At the end of this episode, in which John gave a presentation about a project that he had done within another group, Paul asks John whether he has also calculated the theoretical minimum of the variable he was interested in. John says that he had not thought about that possibility. Subsequently, Paul writes the variables he assumes to be important on a whiteboard, developes them into equations and deduces a formula for the theoretical minimum. This is a nice example of on the spot calculating or trying. The distinguishing characteristic of this type of move is that something new is developed, not before uttering it, but while showing it publicly.

EXPRESSING OBSERVATION

The expressing of an observation consists in the description of what one observes at that very moment. One might think of people looking through a microscope together and describing what they see. This occurs for example in E56, in which Jason and Rick look through a microscope together to observe scratches they made to test a coating. They both express what they observe.

4.3. Discussion of moves

This taxonomy of moves used in technical communication between researchers gives a feeling for the heterogeneity of communication in industrial research. Probably none of the moves as such will be surprising to the reader. No one will be surprised by the finding that researchers describe their results, give arguments and refer others to literature. Nevertheless, I will argue in this section that the overview of moves is a contribution to the literature. Within the existing literature on knowledge processes a comparable taxonomy is lacking. Boland and Tenkasi (1995) suggest that Wittgenstein's (1953) model of language games, a precursor of speech-act theory, is a useful perspective in the analysis of communities of knowing, but they do not present an overview of acts within language games.[17] In chapter one, I explained that the content of technical communication in research is seldomly explored. Myers and Marquis (1969: 81) discerned different kinds of information used in innovation – but the origin of their classification is unclear. Johnston and Gibbons (1975) improved the

[17] They also express some reluctance to operationalize this perspective and give no analysis of the types of moves within language games. They cite the following quote of Wittgenstein (1953: par.23): *"But how many kinds of sentences are there? ... There are countless kinds: countless different kinds of use of what we call "symbols", "words", "sentences". And this multiplicity is not something fixed, given once and for all; but new types of language, new language-games, as we may say, come into existence, and others become obsolete and become forgotten."* But this does not preclude that within a certain community or type of community, at a certain moment in time, a taxonomy might be made, like is done in this thesis. Searle (1979) even proposed a general classification of speech acts. He distinguishes five types: assertives, directives, commissives, expressives and declarations (see chapter one). Most of the moves in my list are to be classified as assertives and directives. Assertives tell something about the world. All descriptions and some of the proposals (like hypothesizing and concluding) fall in this category. Directives are attempts by a speaker to get a hearer to do something. Warnings and questions, among others, fall in this category. However, Searle's classification cannot be very neatly matched to my taxonomy.

taxonomy of Myers and Marquis. Subsequently, Faulkner and Senker (1995: 52) based themselves on Johnston and Gibbons, but enlarged their perspective to 'scientific and technical inputs' to innovation, including personal skills and material resources. In Table 4.2 I compare my taxonomy with that of Johnston and Gibbons. This comparison shows that the overview of Johnston and Gibbons covers only a small part of my moves. It is interesting to note that all but one of their 'contents of information' are limited to what I have labeled descriptions. The contents of information discerned by Johnston and Gibbons seem to be descriptions of facts, of states of affairs.

Another attempt to gain insight in communication processes in scientific and technical problem solving can be found outside the field of organization studies. In the cognitive problem solving tradition of Simon and Newell, Okada and Simon (1997) executed experiments on 'collaborative discovery'. Couples were observed while solving a simulated scientific problem by executing and interpreting experiments. Their communication was recorded and communicative acts were coded into 15 categories. Table 4.2 also compares these categories with my codes. Several things can be noticed. First, only a limited amount of my codes can be recognized in the codes of Okada and Simon. Moves that are not included in their analysis are for example 'reporting about others', 'describing own problem', 'referring to person', 'suggesting research activity' and 'instructing'. These moves assume a world outside a particular interaction, with other people, other activities and knowledge not immediately arising from a single experiment. This is not surprising since Okada and Simon only used a single, isolated and well-defined simulated research problem. A second thing that may be noted from this comparison is that the categories of Okada and Simon match quite well with a subset of my taxonomy. However, their codes are more detailed, which makes that one move of mine might correspond to two or more of them.

The partial taxonomies presented by Johnston and Gibbons and Okada and Simon do not intersect at all. This can be understood from their methodological differences. Johnston and Gibbons (1975) asked their subjects to report information used in innovations in retrospect. Okada and Simon (1997) observed communication in an experimental problem solving setting. Both methodological approaches yield only partial results. This is an illustration of the statement of Okada and Simon (1997: 109) that a combination of different research approaches (historical case studies, field observation, interviews and experiments) is necessary to produce a full and accurate picture of collaboration in scientific research. Still, many moves were not identified at all in these studies. But the fact that all of the classes of Johnston and Gibbons and Okada and Simon correspond to moves found in my empirical research is an indication for the completeness of my findings.

The moves described above all have a direct scientific-technical content or aim. Research-related interactions also consist of moves of a more social character. Researchers ask for time and thank each other. In predominantly research-related interactions they change to telling jokes, muttering about management, talking about politics, soccer or cars, or whatever they like. They engage in metacommunication, discussing their own communication patterns (Watzlawick, Beavin and Jackson 1968: 40). That these moves are not described above does not mean that the importance of these types of moves is not recognized. They are of utmost value for building and sustaining pleasant and fruitful relationships. However, they were beyond the scope of this research.

Taxonomy of moves	**Johnston and Gibbons (1975)**	**Okada and Simon (1997)**
Reporting about others	Existence of specialist facilities or services; Location of information	
Describing own activities		
Describing own knowledge	Location of information	
Describing own problem		
Describing findings or theory	Theories, laws, general principles	
Describing earlier interaction		
Describing experiment	Test procedures and techniques	
Describing own results		
Describing technology	Properties, composition, characteristics of materials or components; Design based information; Existence or availability of equipment or materials with particular properties	
Hypothesizing		Hypothesis; Alternative hypothesis; Extension of hypothesis; Prediction of result
Suggesting technical solution		
Suggesting experiment		Plan for new experiment to test hypothesis
Suggesting research activity		
Warning		
Instructing		
Referring to person	Location of information	
Referring to literature / interactions	Location of information	
Giving arguments		Justification through experimental results; Justification using several

		experimental results; Testability (talk about whether an hypothesis can be tested); Argument about justification
Agreeing		Agreement
Rejecting		Critique
Concluding		Suspending conclusion
Redescribing & summarizing		Summary of data
Asking a question		Requests for explanation
Questioning		Argument about justification
Asking for help		
Showing		
Handing over publications		
On the spot calculating / trying		
Expressing observation		Description of result

Table 4.2: Comparison of moves with Johnston and Gibbons (1975) and Okada and Simon (1997).

4.4. Taxonomy of research-related effects

Communication usually has an effect upon the persons involved. Speech act theory speaks of perlocutionary effects. The focus of this research was on the contribution of technical communication to the practice of industrial research. In line with that focus, I discerned only research-related effects. That implies for example that influences on the feelings of those involved are not mentioned. In the final section of this chapter I will shortly discuss such other types of effects, in order to place the current results in context. In this research several types of research-related effects of communication between researchers were found. The main types of research-related effects are: (1) change in someone's problem portfolio; (2) a contribution to a solution; (3) change in background knowledge; (4) change in knowledge about others; (5) undertaking new actions after the interaction; (6) undertaking new actions within the current interaction; and (7) changing the degree of consensus. Most of these types of effects are subdivided into more specific effects. Table 4.3 summarizes these main types and sub-types of effects and indicates in how many episodes, out of a set of 227 episodes, they were observed.[18] Below they will be described in detail. Later I will come back to the distinction between direct and indirect contributions.

[18] See also Appendix 7. When different subtypes have occurred together, the main type of effect has only be coded once. Therefore the frequencies of the subtype do not add up to the frequency of the main type.

Direct contributions	*Indirect contributions*
Change in problem-portfolio (27) - new problem (17) - structuring problem (11) *Contribution to a solution (59)* - new technical solution (20) - new explanation or theory (12) - new data or observations (14) - new experiment or experimental ability (8) - change of justification (22) - formation or change of degree of belief (33) *Activating after interaction (45)* - activating to communicate (22) - activating to think about a problem (8) - activating to measure (8) - activating to try or use experiments (12) - activating to try or use a technical solution (6)	*Development of background knowledge (28)* - development of questions and interests (4) - development of background knowledge (26) *Development of knowledge about others (104)* - development of questions and interests (21) - development of knowledge about activities of others (56) - development of knowledge about problems of others (47) - development of knowledge about knowledge of others (21) - development of knowledge about literature and interactions (10) - *Activating within current interaction (106)* *Changing degree of consensus (19)*

Table 4.3: Taxonomy of research-related effects

CHANGE IN PROBLEM-PORTFOLIO

In this research project, the job of a researcher in industrial research is considered to consist of creating and solving problems. With that point of view I join authors from several fields. In the philosophy of science, Popper describes science as problem solving. Popper (1963: 222) states that science starts from problems and progresses from problem to problem. Authors in the sociology of science (e.g., Fujimura 1988) and innovation management (e.g., Frischmuth and Allen 1969) have interpreted the work of researchers as the construction and solving of problems too. In the problem solving tradition of Newell and Simon (1972), the cognitive scientists Dunbar (1995), Okada and Simon (1997) and Klahr (2000) have investigated the process of scientific discovery as a special case of problem solving. In the tradition of Simon and Newell it is assumed that problems and problem spaces are given (Dorst 1997). Others, like Schön (1983), have in stead focused on the construction of problems. Both in science and in industrial research, the existence of problems cannot be taken for granted.

Both the Nat.Lab. and OGIR describe their missions as generating innovative technological options. In order to so, several types of problems might have to be solved. These include, for example, answering fundamental scientific questions, solving technical problems and designing experiments. Problems are not a nuisance to researchers. They are necessary to earn their daily bread and researchers usually take pleasure and pride in solving them. Most researchers work on more than one problem. This is in the first place because they might be working on more than one topic. In the second place it is because one topic might involve a set of interrelated sub-problems. Separate problems might be divided into hierarchically ordered sub-problems. If someone is working on a certain problem, say, looking for the cause of a certain phenomenon, the possible solutions to that problem are not given from the start. But when a possible solution is being discovered or created, that might in turn create the problem of how to test or develop that solution. In that way a new, subordinated, problem is created. That sub-problem might in turn lead to new, hopefully smaller, sub-problems. Therefore I think it is useful to speak of researchers working on a problem portfolio.

One possible effect of technical communication is a change in someone's problem portfolio. This change can take two forms. The first type of change is the addition of a new problem. This might be caused by someone else telling about a problem, suggesting to pursue a new research question or instructing to perform a certain piece of research. It might also be that someone else unconsciously points a researcher at a problem. In E40 Jason was asked: "*Does gravity have any effect here?*" Because Jason had not thought of that possibility it raised a new problem for him: finding out if gravity has an effect. Problems need not be very elaborate. It may also be simple questions that evolve. Some interactions lead to the problem of how to test or justify a certain hypothesis or solution. This is a new sub-problem, brought about by the formation of a new hypothesis or solution, or by the questioning of such a hypothesis or solution. As Andrew remarked in response to criticism received at his presentation described in Vignette C: "*You start looking for ways to prove that 'after-pressure' does not matter*" (E153). Another type of change in a problem portfolio is bringing about a change in responsibility. For example, in one episode the responsibility for the topic of spin coating was transferred from David to Jason.

A second type of change in someone's problem-portfolio that might be caused by communication is the structuring or restructuring of the problem a researcher is working on. This may involve that the relation between the (sub-)problems one is working on is made clearer or is changed. It may also involve choosing a research focus, changing the priority given to problems or developing a sequence in which problems will be tackled.

CONTRIBUTION TO A SOLUTION

Technical communication can be of direct use by yielding (a contribution to) a solution to a research problem. A contribution to the solution of a problem can take several forms. First, communication might lead to receiving or developing the content of a new potential solution. Most problems have a large amount of possible answers, most of them inadequate. But as long as one does not know which solution is adequate, receiving any potential solution might be useful. Each potential solution may turn out to be a right solution. But it may also turn out to be a dead alley. Second, communication may yield justification for a particular solution. Third, communication may change one's belief in a solution.

A distinction was made between four different types of solutions: (1) the first effect is that someone arrives at a new technical solution for a problem or sub-problem. In addition to completely new solutions, this also refers to an elaboration upon an existing solution; (2) a second possible result is a new explanation, theory or prediction. This should be regarded as receiving a new hypothesis. A hypothesis may also consist of a visual image. For instance, the OGIR-member Richard stated that he developed a clearer image of the cohesion mechanism between two materials at a micro-scale. He envisioned it on human scale, like he could walk through it (OGIR 010605); (3) communication may lead to new quantitative or qualitative data or observations necessary to solve a problem; (4) the last possible type of solution effectuated by communication is a new option for an experiment, or the acquisition of experimental skills that are relevant for a current problem. If a solution, such as the acquisition of experimental skills, is not directly useful for a current problem, but might be of later use, I coded it as background knowledge (see below). These four types of effects refer only to the content of a solution, irrespective of the degree of belief someone has in it, the eventual justification one has for it and the solution's quality.

These four types of possible solutions correspond to some degree to Vincenti's classification of types of knowledge used by engineers. Based on detailed investigations of the work of airplane engineers, Vincenti (1990) concluded that these engineers use six types of knowledge: fundamental design concepts, theoretical tools, quantitative data, design instrumentalities, criteria and specifications and practical considerations. The first four of them, in that order, correspond more or less to the types I have distinguished. The latter two have not appeared in my research. Presumably that is caused by the fact that fundamental researchers have less to do with practical considerations and design criteria. However, as arguments they might turn up in the next type of a contribution to a solution.

A fifth type of contribution to a solution is receiving new justification for a potential solution. This means getting new arguments for or against a possible solution, or learning about advantages or disadvantages. The change of justification may come from the reception of new evidence. It may also come from the recognition of existing beliefs as an argument. Also the fact that a possible solution is proposed by a particular person can be considered as an argument, as a source of justification. If an expert states a claim, there is more reason to believe it. In that case receiving a possible solution and receiving justification of that solution go hand in hand.

Finally, interactions can lead to the formation of a degree of belief or to changes in the degree of belief one attaches to a possible solution. A degree of belief may be interpreted as the subjective probability someone attaches to a hypothesis or a subjectively experienced degree of uncertainty (Goldman 1999; see also Allen's (1977) solution development records). A change may be either positive or negative: one may increase or decrease one's degree of belief. In some cases full belief might be proved to be unwarranted, leading to an increase of subjectively felt uncertainty. Changes in the degree of belief someone attaches to a possible solution can be expected to be correlated with changes in the justification he possesses for that solution.

I take a complete solution to consist of three parts: the content of a solution, a justification for it and belief in it. Not all contributions to a solution will become part of a final solution. Many proposals may turn out to be dead alleys. This tripartition of content, subjective probability and justification is in line with the analysis of knowledge presented in the next chapter. This is not surprising. My understanding of the concept of knowledge and my empirical research findings mutually shaped each other. However, one element is lacking in the description of the elements of a solution when compared to my working definition of knowledge: the requirement of adequacy. A content, a degree of belief and justification correspond to merely justified belief. The criterion that beliefs have to be adequate is not used. The major reason therefore is that it is impossible for a bystander to judge the adequacy of a solution.

Although technical communication contributes problem solving, it is improbable that it can do the whole job. As one of the researchers at OGIR remarked "*You are being requested to work on a problem that has never been solved before*" (OGIR 010530). Therefore it is improbable that others will be able to provide the complete answer. Answers to sub-problem might be available. But technical communication cannot be the only source of knowledge. Tests, experiments, simulations and calculations must accompany them. These are often necessary for the evidence. Interactions and experimental work can substitute for each other to some extent, but not completely.

DEVELOPMENT OF BACKGROUND KNOWLEDGE

Background knowledge refers to knowledge that someone has and can use for working on a problem. The acquisition of new knowledge was labeled 'development of background knowledge' when this new knowledge is not an answer to an actual problem, but might eventually be used in working on some future problem. Think for example of hearing about a certain theory that is not useful for one's current problems but that might be useful for future problems. Rosenbloom and Wolek (1970: 39) speak in this regard of 'competence-oriented communication' as different from 'problem-oriented communication'. With regard to the acquisition of background knowledge a distinction can be made between: (1) the development of questions and interests in topics not immediately relevant to one's problems; and (2) the development of background knowledge itself. This new background knowledge can be an answer to an existing question. But it may also be knowledge that was not explicitly wanted before. With regard to the acquisition of background knowledge it was possible to make the same distinctions as was done with regard to contributions to a solution. However, for pragmatic reasons I decided not to do that.

DEVELOPMENT OF KNOWLEDGE ABOUT OTHERS

Another research-related effect of technical communication is the development of knowledge about others. The following sub-types can be distinguished: (1) the development of questions about or interests in others and others' research activities; (2) the development of knowledge about activities of others; (3) the development of knowledge about problems of others; (4) the development of knowledge about the knowledge of others; (5) the development of knowledge about existing literature and (future) interactions. These forms of knowledge about others are particularly useful for future technical communication. The importance of gaining knowledge about the knowledge of others has been stressed in the literature on transactive memory systems (Wegner 1987; Hollingshead 1998a; Moreland 1999). This knowledge about the knowledge of others enables the search for knowledge. On the other hand, knowledge of the research problems of others makes it possible to help others. I will come back to these uses of knowledge about others in chapters six and seven.

ACTIVATING AFTER AN INTERACTION

The previous types of research-related effects were either concerned with the development of problems or the development of knowledge or dimensions of knowledge. Technical communication may also lead to actions. According to Searle (1979) that is the normal perlocutionary effect of directives such as questions and orders. The following types of activation have been distinguished: (1) technical communication might lead to new communicative actions. This may be the result of referring someone to another person. This effect is often associated with the previous type of effect, the development of knowledge about others; (2) technical communication may effectuate that someone starts thinking about a particular topic or question; (3) technical communication may lead to the execution of a measurement, for example to test a hypothesis; (4) technical communication may lead to trying or using a certain experiment or experimental equipment; (5) technical communication may lead to trying or using a technical solution. These forms of activating are comparable to what is called 'instrumental use' in the knowledge utilization literature (Menon and Varadarajan 1992).

ACTIVATING WITHIN AN INTERACTION

An obvious effect of communication, but nevertheless important, is that it leads to reactions. Many episodes consist of at least two-way communication. A typical move leading to reactions is asking a question. But also other types of moves lead to moves by others. This effect is called 'activating within an interaction'. Activating within an interaction does not only refer to giving reactions. It includes being activated to think about a certain problem at that moment. Activating within an interaction means evoking a new process of origination (see chapter six). The relationship between origination, moves and effects is cyclical.

CONSENSUS

The effects described above are primarily individual effects. But research is not an individual affair. This is exemplified by the fact that in some interactions participants actively strive after the establishment of mutual agreement. Also the creation of consensus can be therefore be distinguished as a research-related effect. Consensus might be reached with respect to most of all the factors described above. We speak of consensus when there is an explicit assent to a discussed topic. The issue of consensus is explored thoroughly by sociologists of science and technology (e.g. Knorr-Cetina 1981; Lynch 1985; Collins and Pinch 1993). I will not pay much attention to it in this thesis.

4.5. Discussion of effects

In the previous section I presented a taxonomy of research-related effects of technical communication in industrial research. Like there is a variety of moves to be found in technical communication, I observed a variety of effects as well. Most of these effects have been noticed in some form in the literature before, as is indicated by references I gave in their discussion. These different effects are different ways in which technical communication can contribute to researcher practices. Each of these effects has its use. Problems are necessary to do research, solutions are directly useful, background knowledge might be of later use, knowledge about others is valuable for later communication, activating is useful when the resulting actions are useful and consensus can be a precondition for further cooperation.

Nevertheless some effects are more directly useful than others are. We may distinguish between direct contributions and indirect contributions. Direct contributions become directly part of the process of constructing and solving problems. The categories 'change in problem-portfolio', 'contribution to a solution' and 'activating after interaction' consist of directly useful effects. They are immediately relevant for the activities of the researcher involved. On the other hand, the 'development of background knowledge' and the 'development of knowledge about others' do not contribute directly to the construction and solving of problems by a researcher. They might be of later value. The effects 'activating within an interaction' and 'consensus' may be both directly useful and indirectly useful. Therefore I will leave them out of the distinction between direct contributions and indirect contributions. It is obvious that the distinction between direct contributions and indirect contributions is not very sharp. For example, some hypotheses might be tested only after some long period of time, whereas some background knowledge might turn out to be useful on a relatively short term.

Given this distinction between direct contributions and indirect contributions it is noteworthy that indirect contributions are slightly more common than direct contributions. The type of effect that is occurring most frequently after evoking reactions, is the development of knowledge about others. Out of 227 episodes, 111 yielded an indirect contribution, i.e., an increase in background knowledge or an increase in knowledge about others. Direct contributions were observed 101 times. This means that a large amount of technical communication does not contribute directly to the construction or solving of research problems. This should not be interpreted as a shortcoming. Communication that is not directly useful often serves as an investment for the future. As Garud and Nayyar (1994) point out, knowledge that does not seem to be a useful at one moment in time, might become relevant years after. For example, in E256 Frank asks Karl about research results produced more than ten years ago. At that time, these results were considered as by-products. But a decade later they prove to be valuable to Frank. Likewise, communication that is not directly useful, may turn out to be valuable in the near or faraway future.

I would like to draw attention to some more general findings concerning the effects of technical communication. Effects do not arise automatically. Several more or less obvious relationships exist between moves and effects. For example, when someone tells about one of his problems that will often lead to an increase in his interlocutors knowledge about his problem. But moves alone are not necessary and sufficient causes of particular effects.[19] One move can have different effects. This is, for example the case at many presentations. While one person may find something useful in it, somebody else will not. Moreover, moves do not only lead to an effect by being absorbed. Moves may bring forth unintended effects. These may be valuable as well, for example when a move brings someone upon a different idea. Whether a move has a particular effects depends as well upon several of the factors mentioned in the second column of Appendix 4, such as absorptive capacity and the Not-Invented-Here-syndrome. Furthermore, effects can often not be attributed to a single move. It may be a combination of moves that is necessary for a particular effect. Respondents have often told about the value of a particular interaction in general, and not on the value of specific moves. But as John remarks (NL 990921): *"It is like you have to be stung a couple of times before you feel it. Apparently I hear it, I feel it, but it stays unconscious. When it is said some times more, it will appear on the surface."* This makes it possible that an interaction or a part of an interaction has no research-related effect at all. For example because one is already very familiar with what is being said or because one does not understand a iota of it. However, in very few cases I was not able to code for any of the effects. It is always possible one person changes his opinion about the knowledgeability of another person. Something that is not necessary for an effect, is the existence of a question. Moves may fill the hole associated with an unanswered question, but moves may also learn something where no question existed beforehand. This holds as well for direct contributions as indirect contributions.

It should be noted as well that the model of technical communication should be interpreted iteratively and interactively. Episodes of communication are made up of a range of moves, made by more than one person. Likewise, an episode can have several effects, differing for the participants. Moves, effects and origination mechanisms are linked iteratively. Effects can in turn be the basis for new initiatives. This is most clear in the effect labeled 'activating within an interaction'.

The research-related effects summed up above are not the only effects of communication. Other obvious effects are the following. First, communication has emotional effects. People can enjoy conversations or get frustrated by them. Second, communication is not free of costs. It costs time to communicate. Researchers spend a considerable amount of time on communication, to the extent that they feel that other activities are jeopardized. At OGIR some spoke of 'meeting-tiredness'. Orlikowski (2002) found that intensive face-to-face communication in a geographically dispersed organization could lead to burn-out. The cost of communication is acknowledged both in the information processing approach and

[19] See Mohr (1982) for an illuminating discussion of necessary and sufficient causes.

the knowledge-based theory of the firm. But some of the knowledge management literature seems to suggest that more knowledge sharing is always better. Third, communication may bring about changes in relationships. Like a social setting influences communication, communication might in turn reinforce or change relationships. Having talked once to somebody may increase the approachability of that person. One of the researchers of the Group Buijs said: *"A lot of work is done at the corridors. (…) Partly that is gossiping. 'I tell you something and therefore you are my friend. The function of that is to build trust. That makes it possible to go and ask for advice later."* (NL 990622). Further, technical communication may influence the prestige of researchers (e.g., Blau 1963; Allen 1977; Latour and Woolgar 1979). Smart contributions may increase one's status, whereas asking for help may be interpreted as a loss of face.

The taxonomies of moves and effects show how technical communication forms an integral part of the industrial research. In the remainder of this thesis these taxonomies will be used in two ways. In the next chapter I will reflect theoretically upon them, assessing what they imply for the interpretation of technical communication in terms of knowledge transfer, information transfer and the reduction of uncertainty and ambiguity. That is, I will examine whether these findings support or subvert the knowledge-based theory of the firm and the information processing approach. In chapter six I will relate moves and effects to origination mechanisms. I will show that different types of moves and effects are associated with different types of origination.

5.

COMMUNICATION, KNOWLEDGE AND INFORMATION

This is the first theoretical chapter. In this chapter the investigation of moves and effects will be made productive in criticizing basic assumptions about technical communication offered by the knowledge management literature and the information processing approach. I will concentrate first on the interpretation of technical communication as knowledge transfer. In order to evaluate this interpretation, the concept of knowledge will be discussed first. Using 'justified adequate belief' as a partial working definition, the following conclusions will be drawn:

- *not all useful technical communication can be interpreted as knowledge transfer, since (1) some instances of useful technical communication have other research-related effects than an increase in knowledge; and (2) some instances of useful technical communication only yield 'building blocks' for knowledge*
- *some moves and effects are better described as knowledge-conducive communication; this plays a different role in industrial research practices*

The IPA explains the contribution of technical communication to research performance by identifying useful communication with information transfer and the reduction of uncertainty or ambiguity. However:

- *Shannon and Weaver's technical interpretation of information is not relevant for describing the contribution of technical communication*
- *if Dretske's epistemological interpretation of information is used, not all useful technical communication qualifies as information transfer*
- *only one interpretation of information as meaningful data supports the assumptions of the IPA; however, this is not a very informative interpretation*
- *technical communication does not only reduce uncertainty or ambiguity; it may also increase uncertainty or ambiguity; this calls into question the heart of the explanation of the usefulness of technical communication proposed by the information processing approach*

5.1. Introduction

In chapter four I presented supposedly exhaustive taxonomies of moves and research-related effects of technical communication in industrial research. These overviews show technical communication to be a heterogeneous activity. Nevertheless, in the extant literature it is often referred to by single concepts. I explained in chapter one that the well-established tradition of research on communication in research and development interprets technical communication as information transfer or information flows. In the more recent knowledge management literature, communication is often portrayed as knowledge transfer. These interpretations play a central role in the theoretical explanations of the value of technical communication offered by the IPA and the KBT. To subsume heterogeneous phenomenona under a single concept is not necessarily mistaken. On the contrary, using more abstract concepts improves our cognitive efficiency (Hatch 1997). It may be quite useful to use the word 'bird' to refer to blackbirds, bluebirds, swallows, sparrows and housemartins. However, if such a more abstract concept like knowledge transfer or information transfer is used to cover all types of technical communication, this should be justified on the basis of the meaning of the abstract concept.

In this chapter I will examine the questions whether technical communication can be identified as information transfer, as knowledge transfer and / or as reducing uncertainty or ambiguity. The verb 'transferring' will not be called into question (I leave that to later chapters). What I want to explore is whether the object that gets transferred, if any, can be correctly interpreted as knowledge and / or information. I will examine first whether useful technical communication can be interpreted as knowledge transfer. If the interpretation of technical communication as knowledge transfer is taken seriously, this means that *all* communication is knowledge transfer. However, many would refrain from that statement, by acknowledging, for example, that there are cases of failed or useless communication in which no knowledge is transferred. Therefore we should focus on the weaker claim that useful technical communication consists of knowledge transfer. Useful technical communication is communication that contributes to research practices, to the performance of research groups. The examination of this claim is particularly relevant for an evaluation of the explanation of the value of technical communication by the knowledge-based theory of the firm.

In the second place I will turn to the question whether useful technical communication can be interpreted as information transfer. Many authors assume that (useful) technical communication can be interpreted as the transfer of information (e.g. Johnston and Gibbons 1975; Allen 1977; Tushman 1978; de Meyer 1985; Moenaert and Souder 1996; Maltz 2000; more references in chapter one). In information processing perspectives it is acknowledged that not all technical communication is information transfer, since it may fail or be of no use (Tushman and Nadler 1978: 614). I will also evaluate the claim that all useful technical communication reduces uncertainty or ambiguity. These conceptual discussions are directly relevant for explanation of the contribution of technical communication to research performance offered by the information processing approach.

The detailed analysis of technical communication presented in the previous chapter provides the means for examining these assumptions of the knowledge-based theory of the firm and the information processing approach. To analyze the claims linking technical communication, knowledge, information, uncertainty and ambiguity, I will draw in the first place upon the range of moves and effects found in my empirical study of technical communication. These taxonomies serve as a touchstone. In chapter four I explained that all of the discovered effects can be valuable. They represent different contributions of technical communication to the practice of industrial research. Therefore the concepts of knowledge transfer, information transfer and the reduction of uncertainty or ambiguity should be able to cover each of those effects. In addition, I need an analysis of knowledge. Therefore I will start with a discussion of the concept of knowledge in the next section. In section 5.4 I will draw upon different conceptualizations of information. These conceptualizations will not be evaluated on their intrinsic merits. They will be used to determine whether the heterogeneity of technical communication can be subsumed under the concept of information transfer.

5.2. Knowledge

Epistemologists have traditionally analyzed knowledge as 'justified true belief' (Russell 1948; Moser 1995; Audi 1998; le Morvan 2002). This tripartite definition dates back to Plato's *Theaetetus*. It can be understood as follows. According to almost all epistemologists, knowledge is a subspecies of beliefs. Knowing that something is the case, entails believing that that something is the case (Luper 1998). Following these epistemologists, the utterance 'I do not *believe* it, I *know* it!' is self-contradictory. However, not all beliefs qualify as knowledge. The quality criteria most often applied are that beliefs need to be both true and justified to count as knowledge. It is inappropriate to say that you know that there is a red car outside, when there is no such car. A belief needs to be true. But some true beliefs do not qualify as knowledge either. A belief should be grounded in evidence or have been established in a reliable way. That is, it needs to be justified. A blind guess that turns out to be true does not count as knowledge. Much debate has centered on kinds of justification and the required level of justification (e.g., Goldman 1986; Pryor 2001). This standard analysis of knowledge has been criticized in two directions. First, the criteria of truth and justification have been put under attack (e.g., Gettier 1963; le Morvan 2002). Second, some writers have considered the category of belief to be not the right or only category under which knowledge can be subsumed. This means that a choice for a particular interpretation of knowledge requires some more reflection.

Most epistemological discussions during the last decades have centered on the criteria that beliefs should meet in order to qualify as knowledge (see Pryor 2001). Gettier (1963) wrote a three-page article in which he gave ingenious examples of justified and true beliefs, which would not be counted as knowledge. Since that article, several new criteria have been proposed and new theories of justification have been developed (e.g., Dretske 1981; Goldman 1986). Most of them boil down to posing even stricter requirements, like 'the right kind of justification'. One example of such an alternative theory that has become known in the field of organization science via Nonaka (1994), is Dretske's externalist account of justification.[20] Dretske (1981) analyses knowledge as 'information produced belief', whereas information is that commodity that is capable of learning us something in an infallible way. Others have argued that the justification condition can or should be dropped. In that perspective, knowledge is merely true belief (e.g., Goldman 1999; le Morvan 2002). Pragmatists have argued that it is not truth that matters, but usefulness (James 1907; Churchland 1985). Pragmatists have considered theories to be instruments for explanation and prediction. These instruments should be evaluated on their effectiveness. This might especially be relevant for technological knowledge. Technological rules urge one to take certain actions. Effectiveness seems to be a better criterion for technological knowledge than truth. Sociologists of science have argued that the distinguishing characteristic of knowledge cannot be found in some objective criterion, but in its degree of acceptation (e.g., Barnes and Bloor 1982). According to them, knowledge consists of socially accepted beliefs. Finally, Goldman (1986: 19) notes that "*Many writers, especially in the behavioral and social sciences, use 'knowledge' in an ultra-loose sense, to mean simply belief, or representation of the world. This is probably a misuse, though one so common that perhaps it has achieved legitimacy*".

Not only the criteria for knowledge are in dispute, also the category of 'belief' is. Critique on the notion of belief stems from several directions. First, findings from the field of cognitive science question the full adequacy of the notion of belief. Cognitive scientists have seldomly been interested in epistemological criteria, but the more in the form that knowledge takes. Cognitive scientists have also discussed knowledge in

[20] Internalist theories of justification look for justification in other beliefs and evidence one possesses. Externalist theories of justification look for justification in the way a belief has been caused (Pryor 2001).

terms of cognitive models, schemes, scripts, visual images, pictorial representations, procedural memory and neural networks (e.g., Paivio 1986; Churchland 1992; Anderson 1983; 1990; Motzkin 2002). Second, philosophers have introduced concepts like know-how (Ryle 1949), tacit knowledge (Polanyi 1958), knowledge-by-acquaintance (Russell 1912) and technological rules (Bunge 1967; Meijers and Kroes 2002). Furthermore, some authors have defined knowledge itself as an ability or capacity, as a capacity to act, to decide or to answer questions (Newell 1981; White 1982; Maturana and Varela 1987; Weggeman 1997; Tsoukas and Vladimirou 2001). Some social scientists have discussed knowledge in terms of stories (Bruner 1986; Orr 1990). Foucault has described knowledge as a discourse (McHoul and Grace 1995). Economists and organization scientists have defined organizational knowledge as routines (Nelson en Winter 1982; Levitt en March 1988). Some even speak of embedded knowledge – knowledge that is not carried by humans but by products, tools and instruments (Latour 1987; Blackler 1995).

It is questionable whether these alternative forms of knowledge can all be subsumed under the concept of belief. Most philosophers consider beliefs to be one kind of propositional attitudes: an attitude taken toward a proposition (Searle 1983: 15; Dienes and Perner 1999). A proposition is that what can be expressed in a sentence. The sentences 'Snow is white' and 'Schnee ist weiß' express the same proposition. The attitude that characterizes a belief is that a proposition is considered to be true. According to some cognitive scientists and philosophers, alternative forms of knowledge are reducible to belief-like propositional structures (e.g., Smolensky 1988; Dienes and Perner 1999; Stanley and Williamson 2001). Others have doubted or denied that (Ryle 1949; Paivio 1986; Goldman 1986: 252; Thagard 1988: 200; Churchland 1992; Motzkin 2002; Meijers and Kroes 2002). Unfortunately, this discussion is not very much alive in the mainstream of recent epistemology. Most epistemologists take the core category of beliefs for granted (see for example Audi 1998; Pryor 2001). But, even if it would be true that all knowledge is ultimately reducible to belief-like structures, different knowledge types are at least phenomenologically different. That is, we experience them as different. We experience proposition-like knowledge (for example, my belief that there is a laptop in front of me) differently from images and knowing how to ride a bike. Probably, we will deal differently with these types of knowledge as well. At school, for example, belief-based knowledge will be taught differently than know-how.

In this thesis I will proceed as follows. I will use 'justified adequate belief' as a partial working definition of knowledge. This working definition is almost identical to the standard analysis of knowledge. I follow epistemologists in posing quality criteria for knowledge. As I made clear on the first page of this thesis, the importance of knowledge thrives on its adequacy. Furthermore, in order to trust our beliefs, we like to have justification for them. It is not so difficult to have a belief, but often far more difficult to have a belief that is justified and true (or meets other quality criteria). This is especially important in this thesis since the focus is on researchers. Researchers make a living by determining what beliefs meet those quality criteria. However, many organization scientists only struggle to discriminate knowledge from data and information but do not pay any attention to such quality criteria. I use the adjective 'adequate' to cover both truth and other criteria like effectiveness and usefulness. In an industrial, technological environment these latter criteria seem to be as important as truth. The use of the term 'adequate' is not meant to imply any conceptual progress, but serves as a semantical simplification. By using this definition I do not follow social constructivists in their claim that the defining characteristic of knowledge lies its degree of social acceptation.

As explained above it is improbable that the notion of belief is capable of covering all types of knowledge. For that reason I propose 'justified adequate belief' as a *partial* definition of knowledge. Our knowledge encompasses visual images, know-how and technological rules (etc.) as well. Unfortunately, I know of no other phrase to describe these other types of knowledge, if they indeed differ from beliefs, than 'non-belief-based knowledge' (Meijers and Kroes 2002).[21] Considering the scope of this rest-category, I choose in this thesis to reserve the concept of knowledge for humans. Beliefs can only be attributed to humans. Therefore, belief-based knowledge can only be carried by humans.[22] In line with that, I do not consider texts or technological artifacts as knowledge or carriers of knowledge. Furthermore, non-belief-based knowledge should meet quality criteria as well. I assume that 'adequacy' and 'justification' are adequate for these types of knowledge as well.

In the remainder of this chapter I will work only with the partial definition of knowledge. This is not a serious problem. To show the inadequacy of the interpretation of technical communication as knowledge transfer, it is enough to show the inadequacy for a subset of knowledge types. Furthermore, I think that the

[21] The distinction between belief-based and non-belief-based knowledge does not cover the distinction between explicit and tacit knowledge (Polanyi 1958; 1966). Polanyi has described tacit knowledge in terms of beliefs as well. Ryle's (1949) distinction between know-that and know-how matches this distinction more, but the category of non-belief-based knowledge encompasses probably more than know-how. Other typologies of knowledge (e.g., Vincenti 1990; Blacker 1995; Faulkner and Senker 1995; Garud 1997; Meijers and Kroes 2002) might help in structuring the discussion, but these have not yielded more encompassing definitions of knowledge.

[22] And maybe to animals, but that is irrelevant here.

following analyses hold as well when other concepts are used in stead of 'belief', and other quality criteria are used.

5.3. Technical communication and knowledge transfer

In this section I will evaluate the claim that useful communication can be interpreted as knowledge transfer. This assumption seems to underlie much of the literature on knowledge management and the knowledge-based theory of the firm (see also chapter one). For example, Hansen and Haas (2001) refer to Shannon and Weaver's communication theory as a theory of knowledge transmission. The hypothesis can also be derived from two other widely accepted propositions: (1) (useful) communication is often identified with information transfer (see references elsewhere in this thesis); and (2) information is often identified with explicit knowledge (e.g., Kogut and Zander 1992: 386; Anand et al. 1998: 797), verbally encoded knowledge (Moenaert and Souder 1996) or just used interchangeably with knowledge (e.g., Huber 1991). The combination of these broadly accepted propositions yields the proposition that (successful) communication contains the transfer of (explicit) knowledge. In order to examine this claim I will use a straightforward model of knowledge transfer. Transferring knowledge consists of a person A communicating a piece of knowledge to a person B who incorporates that piece of knowledge in his belief system. This is in line with Grant (1996b: 111) and Davenport and Prusak (1998), who state that knowledge transfer encompasses both transmission and receipt.

In this section I will criticize the idea that useful technical communication can always be described as knowledge transfer, but I do not intend to argue that knowledge transfer is impossible. The claim that knowledge transfer is impossible, has been defended on at least three different grounds. First, it might be argued that knowledge cannot be transferred since knowledge cannot exist outside people. Transferring knowledge from one person to another requires the use of phenomena outside people, such as symbols on a piece of paper. Since these phenomena can't be knowledge, knowledge can't be transferred. However, that argument does not hold. It is only required that the initial state of person A and the final state of person B comprise (the same) knowledge. Second, it might be argued that this latter state of having the same knowledge cannot be attained since each person has to reconstruct beliefs in his own subjective semantical network. However, in daily life we experience that people often have the same belief. For example, many meetings can start at a fixed time, because the attendants have the same belief about its starting time. Third, some epistemologists argue that knowledge transfer is impossible because beliefs produced by communication cannot be justified. Epistemologists discuss knowledge transfer in terms of testimony (Coady 1992; Audi 1998; Graham 2000). Plato, Aristotle and others argue that somebody else's testimony is not a good enough reason to believe something (Coady 1992). According to them, testimony is an inadequate source of justification. Since knowledge presupposes justification, this implies that knowledge cannot be transferred by communication. However, though it might be true that we can never be fully justified in believing what others say, this holds as well for sources of justification, such as perception. Moreover, since a large share of what we consider to be our knowledge depends in some ways upon evidence hold by others, it would run against our use of the term knowledge if we excluded all those beliefs from the qualification 'knowledge'. Therefore, I do not reject the very possibility of knowledge transfer.

I will offer two arguments against the idea that all useful technical communication consists of knowledge transfer. First, I will argue that there are types of effects that are not knowledge-related. Second, I will argue that knowledge-related effects do not always consist in the transfer of a full piece of knowledge. These effects, which cannot be described as an increase in knowledge, are valuable as well.

If we look at the research-related effects of communication described in chapter four, we see that not all of them consist of a development of knowledge. Take for example changing the problem-portfolio one is working on. This may consist of discovering a new problem, being pointed at a problem by someone else or structuring a problem differently. These changes do not consist in an increase of knowledge. A problem is not knowledge but an occasion to build knowledge. Of course, changing a problem may be based on knowledge, but this type of effect itself is not an increase of knowledge. Nevertheless, it is useful. Having research problems enables further research. Something similar can be said of the effects labeled 'activating'. To be activated to try something or to think about something is in itself not an increase in knowledge. It might be enabled by new knowledge, but even in such a case, it is not reducible to an increase in knowledge. These examples show that there are useful research-related effects of communication that differ from an increase of knowledge.

This conclusion is supported by speech act theory. Let's compare these two speech acts: 'The door is closed!' and 'Close the door!'. Searle (1979) would call the first speech act an assertive and the second type a directive (see chapter one). A typical perlocutionary effect of the assertive is that the addressee believes that the door is closed (Meijers 2002). A typical perlocutionary effect of the directive is that the addressee closes the door.[23] The perlocutionary effect of a speech act may be a new belief as well as taking an action (and other effects). To a certain extent all successful speech acts lead to an increase in knowledge. If we say 'Hello!' to someone, the other learns that he has been greeted (Searle 1969: 49). If someone says, 'The door is closed!' a hearer may gain the knowledge that the speaker believes that the door is closed. Such an increase of knowledge is directly associated with understanding the speech act. The directive requires that the addressee understands that the sender wants him to close the door. However, this does not mean that taking actions, for instance, is a secondary effect of communication and that an increase in knowledge is a more direct effect. The increase of knowledge associated with understanding a speech act consists in understanding what the speaker means. It does not yet involve believing or not believing what has been said. If one understands that the speaker believes that the door is closed, this might be a reason for the hearer to adopt that belief too. This latter belief would be a perlocutionary effect, like taking an action can be a perlocutionary effect. The one effect is not less direct than the other is. Therefore, communication is not always adequately captured by an interpretation in terms of knowledge transfer.

Before I can proceed with another critique of the idea that the value of communication lies solely in the transfer of knowledge I have to remind the reader of the working definition of knowledge used in this thesis. I explained that the analysis of the concept of knowledge that I would like to use is 'justified and adequate belief'. This analysis of knowledge shows knowledge to be a multi-dimensional concept. It comprises of (1) having a proposition; (2) believing that proposition to be adequate; (3) being justified in believing so and (4) that belief being adequate. A necessary condition to speak of knowledge transfer is that the communicative acts yield an increase of knowledge. In order to speak of knowledge, each of its elements needs to be present. If communication establishes that each of those four dimensions are present, that communication has produced knowledge. In chapter four I explained that the subtypes of contributions to a solution correspond to dimensions of the concept of knowledge.[24] Many episodes yield only one of these dimensions. Most interesting scientific and technical questions do not find easily a justified answer. Solving a problem often involves searching and considering a range of potential answers and

[23] Of course, these speech acts may have other effects too. Speech acts may also be used indirectly. For instance, by uttering 'The door is closed!' one may indirectly command somebody else to open the door.

[24] The dimension of adequacy is absent from the contributions to a solution. First, accuracy (e.g., truth) cannot be acquired independently from propositions and the degree of belief in those propositions (and reality being the way it is). Second, it is impossible to determine this accuracy as a bystander, being not omniscient.

searching and considering a wide range of evidence. When potential answers are available it might take considerable time to find out which one is most justified. For example, researchers at the Group Buijs searched for the cause of the bending of particular polycarbonate optical discs. They considered many causes and tried to eliminate them subsequently. They compared themselves with detectives in a 'whodunit'. At OGIR researchers were designing a new catalyst particle for a certain process. They came up with different shapes, materials and compositions and tested each of them using simulations, known material characteristics and experiments. Finding a solution to such research problems can be a very time-consuming and complex affair. This is also shown in many sociological studies of science (e.g., Collins and Pinch 1993). Colleagues do not frequently provide researchers with justified and adequate answers. They may come up with hypotheses, suggestions for a technical solution or another type of proposal (see Table 4.1). These are alternatives that are not necessarily adequate and not yet justified. In short, they are not knowledge, but 'building blocks' for knowledge. Stein and Ridderstrale (2001) have acknowledged this too. Paraphrasing Polanyi's (1966) famous dictum that 'we can know more than we can tell', they state that people can tell more than they know. With this statement they specifically refer to uttering conjectures that go beyond available evidence. Nevertheless, hypotheses, suggestions and conjectures are extremely valuable for research. They enable further research. Moreover, experimental studies have shown that it is favorable to consider a wide range of alternative possible solutions (Allen 1977).

Comparable remarks can be made for arguments and other types of evaluations. Receiving an argument or evidence does not necessarily imply getting new knowledge. One piece of evidence is often not enough to justify a particular answer. Researchers will often not come to an outspoken believe on the basis of a single argument. The agreement of a colleague may lead one to increase his belief, but not necessarily to full belief. Giving arguments and evaluations does not by itself constitute a transfer of knowledge. This holds a fortiori for asking questions. Asking questions may be very useful, since they might guide future research. They may point at a weakness in the grounds for a certain answer. For example, one member of the Group Buijs was asked at a presentation of a rheological model whether the good fit of his model was not due to the fact that he used eight parameters. This spurred him to examine that possible pitfall. Such questions do not immediately yield new knowledge, nor can they be seen as expressions of knowledge themselves. Questions and hypotheses are not expressions of knowledge or encoded knowledge (Searle 1969: 65). We can conclude that many valuable contributions to a solution are in themselves not knowledge, but building blocks for knowledge.[25] Because knowledge transfer requires an increase of the receiver's knowledge, many valuable communication episodes do not qualify as knowledge transfer. Moreover, even if the effect is new knowledge, this should not necessarily be the result of knowledge transfer. This new knowledge needs not have been transferred completely. For example, if someone gives a crucial piece of evidence, this may offer the receiver the opportunity to 'complete' a piece of knowledge.

We can conclude that not all useful technical communication can be captured by the phrase 'knowledge transfer'. For useful technical communication that cannot be interpreted as knowledge transfer, I propose to introduce the concept of *knowledge-conducive communication*. It refers to moves and effects in which no knowledge is transferred, but which play a role in the process of developing knowledge. They can be interpreted as being part of a social process of constructing knowledge, as described by Latour (1987). Above I argued that some effects are not directly related to the acquisition of knowledge. This holds for changes in a researcher's problem portfolio and for activations. Constructing research problems and undertaking actions, such as experiments, do not in themselves qualify as an increase of knowledge. But they play a role in the knowledge development process. Technical communication that yields problems and activates can therefore be labeled knowledge-conducive communication. Further, some moves and effects only yield single dimensions of knowledge and not complete knowledge. These are also instances of knowledge-conducive communication. Contributions from others that do not provide a complete answer, but only questions, proposals or arguments, can nevertheless be very valuable to the process of knowledge development. In the previous chapter I mentioned the episode (E40) in which Jason is asked, "*Does gravity have any effect here?*". Since Jason had not thought of that possibility he took it as a hypothesis and started to explore it afterwards. In this case it was not knowledge that was transferred – it was a question. Nevertheless, it contributed to a process of knowledge development. I claim that such a move and effect is better described as knowledge-conducive communication. This holds for many of the proposals, evaluations and questions that were found in the episodes studied.

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[25] My second argument against describing the value of communication in terms of an increase of knowledge is based on the premise that the development of single dimensions of knowledge cannot be interpreted as an increase in knowledge. However, the epistemologist Goldman recently proposed a concept that he claims to be applicable as the single measure of knowledge-related value of social practices. This concept is 'veritistic value' (Goldman 1999; 2000). But the concept of veritistic value has its shortcomings as well (see Schmitt 2001; Berends 2002).

5.4. Technical communication and information transfer

5.4.1. Introduction

In this and the following section I will focus upon the explanation of the contribution of technical communication by the information processing approach. According to the IPA, useful technical communication consists in information transfer; this information reduces uncertainty and ambiguity; reduced uncertainty and ambiguity are supposed to yield an increased performance. This line of reasoning is represented in Figure 5.1. But Van de Ven and Drazin (1985: 354) observe that the concept of information is treated as an abstract, latent, unmeasured concept in the empirical research of IPA theorists. This is illustrated by the studies of Tushman (1978), Keller (1994) and others, in which only communication, performance and contingency factors are measured.[26] The performance effect of technical communication is assumed to be realized through information transfer and uncertainty or ambiguity reduction, but whether that is indeed the case is left unanalyzed. However, the detailed analyses of the previous chapter enable an examination of these assumptions. I will evaluate the assumptions (1a) that all useful communication consists of information transfer and (1b) that the value of technical communication lies in the transfer of this information. In section 5.5 I will examine the assumption (2) that useful technical communication reduces uncertainty or ambiguity.

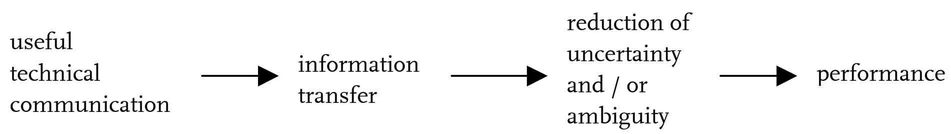


Figure 5.1: Line of reasoning from technical communication to performance that will be evaluated.

To assess the first two assumptions it is necessary to have a precise conceptualization of information. However, the meaning of the term information is far from clear. In the field of organization studies there is no authoritative source to which the majority of authors turn for a definition. Information processing theorists in the field of organization science give some clues about their interpretation of the concept, namely, that it is linked with uncertainty (Galbraith 1973; 1977) and that it should be able to yield knowledge (Tushman and Nadler 1978), but they do not provide us with

[26] Task characteristics, task interdependence and the environment, the main contingency factors studied in the IPA, are left out of Figure 5.1.

an elaborated conceptualization. Both within the field of organization science as in other fields a wide variety of definitions of information exists (see overviews in Machlup 1983; Stamper 1985 and Checkland and Holwell 1998). Authors have different intuitions with regard to the concept. For example, whereas Dretske (1981) holds that information needs to be new and truthful, that it is related to uncertainty and can also be used to describe observation, Machlup (1983) argues that is correct to speak of old and false information, rejects the strong link with uncertainty and reserves the term only for human communication. It is probably save to say that these different definitions only show family resemblances (Wittgenstein 1953: par.53). Some definitions correspond to some degree, but there is no common feature that they all share. Therefore we have to examine different interpretations of information in order to see whether there is an interpretation of information that justifies the claim that useful technical communication consist of information transfer.

In this section I will apply three different interpretations of information. The first is the classical work of Shannon and Weaver (1949) on information theory. A second is Dretske (1981). In his book *Knowledge and the flow of information*, Dretske (1981) offers the most detailed philosophical treatment of the concept of information. The third is the received opinion that information consists of meaningful data. However, we will see that that shorthand-definition is interpreted in different ways as well. I will argue that all but one of these interpretations fail to support the line of reasoning of the IPA. A fourth type of interpretation of information is to equate information with explicit knowledge. However, if that interpretation is chosen, it can be dismissed as a descriptor of successful communication on the same grounds as knowledge was dismissed in the previous section. For that reason I will not discuss it here any further.

5.4.2. Shannon and Weaver

The mathematical theory of communication of Shannon and Weaver (1949) is often referred to as information theory (see also Figure 1.1). According to Checkland and Holwell (1998: 93) 'information theory' is grotesquely mis-named. It would better have been called 'signal transmission theory'. Shannon and Weaver's theory gives a 'technical' interpretation of the concept of information. "*The word information used in this theory, is used in a special sense that must not be confused with its ordinary usage*" (Shannon and Weaver 1949: 99). Unfortunately, this confusion has proliferated in the social sciences.

Shannon and Weaver (1949) state that information is created when a number of possibilities is reduced. The amount of information created at a source 's' by reducing a number of n equally likely alternatives to one is normally determined by a logarithmic function: $I(s) = {}^{2}\log n$.[27] The measurement unit associated with this formula is ‘bits’. This can be read as an abbreviation of ‘binary digits’ (Shannon and Weaver 1949: 4). The reduction of eight possibilities to one generates three bits of information and the reduction of sixty-four probabilities to one generates six bits of information. Shannon and Weaver use this idea in a purely technical sense (in section 5.4.3 we will see that Dretske applies the same basic idea in an epistemological sense). They are concerned with the transfer of signals. They assume that information is generated when a particular message is chosen to be transferred. That message can consist of a sequence of letters or functions of variables (Shannon and Weaver 1949: 4)**.** Take for example the ASCII set of symbols. This set consists of 256 possible signs. The choice for one of those symbols generates ${}^{2}\log 256 = 8$ bits of information. From a technical point of view, the strings of symbols ‘I love you’ and ‘xpadscifdc’ consist of an equal amount of information, namely 10 x 8 = 80 bits.

Shannon and Weaver are interested in the adequate and efficient transmission of signals. They are not concerned with the information that messages carry about reality or the meaning of those messages: “*The fundamental problem of communication is that of reproducing at one point exactly or approximately a message selected at another point. Frequently these messages have meaning; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem*” (Shannon and Weaver 1949: 3). Transmitted symbols may be meaningless or in other ways completely useless. If we follow their interpretation of information, the assumption (1a) that communication is information transfer is probably true. Nevertheless, it is irrelevant with regard to our initial question. Their information concept has nothing to do with the value of communication and therefore subverts assumption (1b).

5.4.3. An epistemological account of information

Dretske is the philosopher who has written the most thorough account of information. He interprets information as an epistemological concept (Dretske 1981). His account still stands out, as is indicated by the fact that he has written lemma’s on information in the recent editions of the *Routledge Encyclopedia of Philosophy* and the *MIT Encyclopedia of the Cognitive Sciences* (Dretske 1998; Dretske 1999). In the field of organization science, Nonaka (1994) uses Dretske as a source to discuss the concepts of knowledge and information. According to Dretske, the nuclear meaning of information is that what a signal is capable of telling us truly about another state of affairs**.** Information is that commodity capable of yielding knowledge, i.e., reducing

[27] For partial reductions of alternatives, e.g., from eight to six, and in case of differing initial probabilities, more complex functions have been developed.

uncertainty (Dretske 1981: 44). This basic idea connects Dretske's analysis to basic assumptions in the information processing approach. For instance, Galbraith (1973) defines uncertainty as a lack of information and Tushman and Nadler (1978: 614) state that information must effect a change in knowledge.

Dretske elaborates the basic idea that information is the commodity capable of yielding knowledge in the following way. He follows Shannon and Weaver in the idea that information is created when a number of possibilities is reduced (Dretske 1981: 4). When eight employees determine who is going to execute a particular task, for example by drawing lots, the number of possible executors is reduced from eight to one. When a pawn is placed on an arbitrary field of an empty chessboard, the amount of possibilities for placing it is reduced from sixty-four to one. Dretske is not interested in the realization of particular symbols from a complete set of possible symbols like Shannon and Weaver are, but in the realization of a particular state of the world. Dretske defines the content of information as follows: *"A signal r carries the information that S is F = the conditional probability of S's being F, given r (and k), is 1 (but given k alone, less than 1)"* (Dretske 1981: 65). In this statement 'k' refers to the knowledge the receiver already has. Conditional probability is the objective probability that something is the case (S being F) given certain background knowledge. A signal r tells us something if it increases this conditional probability to 1, i.e., if it makes us certain. Consider Dretske's example of eight employees determining who will do a particular task. If they agree that Peter will execute this task, three bits of information are created. They can transfer this information on a note to their boss. Initially, the eight possibilities had a conditional probability of 0.125 for their boss. If he receives the note in well order, the conditional probability of Peter executing the task rises to 1. That is, he learns that Peter will do the task (and the seven others not). In Dretske's epistemological notion of information, existing knowledge plays an important role. If a conditional probability is already 1 for someone, i.e. if he is already sure that S is F, a signal cannot carry that information for him anymore. Further, if a receiver lacks relevant background knowledge, a signal becomes uninformative. For example, for a biologist the annual rings in a tree provide information about the age of that tree. For someone unaware of the relationship between annual rings and age, these rings do not carry that information.

Dretske connects information tightly to knowledge and uncertainty. In Dretske's analysis information, knowledge, and uncertainty are objective and absolute concepts. Information is that commodity that is capable of learning someone something in an infallible way. False information is no information at all, like toy ducks are not a particular species of ducks. Information is the potential of a signal to let someone learn something about something. Information exists only in relation to a potential receiver. However, that does not give it subjective characteristics. Dretske stresses that information is an objective commodity. Compare the property of a cube to fit into a round hole. If the hole is large enough, the cube will fit in it. The property of the cube to fit into a particular hole is an objective property, but it depends upon the characteristics of the hole. Likewise, information is dependent upon the knowledge of a potential receiver, but its informative value is not created subjectively by a receiver. Dretske defines knowledge as 'information produced belief'. A belief is only knowledge if it is completely justified by information received. This implies that knowledge is also absolute, objective and infallible (Dretske 1981: 108). It should be noted that Dretske considers 'information produced belief' not as a new theory of knowledge. It is a version of 'justified true belief'.[28] If a belief is produced, or sustained, by information it is fully justified and by definition true. Many authors associate information with uncertainty. Galbraith (1973; 1977) defines uncertainty as the difference between available information and required information. Shannon and Weaver (1949) and Dretske (1981) agree on this point. In Dretske's analysis, uncertainty refers to a conditional probability lower than one. Information may increase this conditional probability, i.e. reduce uncertainty. A degree of uncertainty does not refer to a subjectively experienced degree of uncertainty, like information is not dependent upon human interpretation to be information (Dretske 1981: vii). This means that by definition information cannot increase uncertainty.

At first sight, Dretske yields a conception of information that conforms to our demands. It portrays information as a valuable commodity. Moreover, he gives a specific interpretation of this value. However, the applicability of this concept is limited. According to Dretske, information is created when one possibility out of a set of possibilities is realized. By means of communication this information may arrive at a human receiver. The information a human receives always stems from a particular situation or event. This is underscored by Dretske, who emphasizes that his account of information only holds for perceptual knowledge. Likewise, Graham (2000), who applies Dretske's analysis to knowledge transfer, stresses that his account only holds for communicating knowledge received by the senses. *"So I will not discuss reports about general matters of fact, or about moral matters, or about mathematical matters or matters of necessity"* (Graham 2000: 134). This implies that the concept of information is not applicable to generalizations such as 'all ravens are black'. Information is always about a particular raven. More generally, the concept of information is not applicable to inductively or abductively derived beliefs. These go beyond available evidence. This

[28] Dretske's theory of knowledge entails an externalist theory of justification. An advantage is that it is capable of dealing with Gettier's (1963) counterexamples against the analysis of knowledge as justified true belief.

implies that hypotheses, conjectures, suggestions and questions cannot qualify as information. These typically go beyond existing evidence or are not based on evidence at all. Such moves are not intended to transfer information that originated earlier in a particular situation.

A second problem with Dretske's interpretation of the concept of information, as well as with Shannon and Weaver's, is that it becomes impossible to speak of information in the absence of an awareness of all alternatives (Garner 1962: 3). Information and uncertainty are intrinsically linked. Information is the capability to reduce uncertainty (Dretske 1981: 4). The amount of information a signal carries equals the amount of uncertainty that signal can reduce. Reducing uncertainty means eliminating options or changing the conditional probabilities of options. But a receiver is only able to eliminate an alternative, or change his degree of belief in that alternative, if he knows this alternative. However, often that is not the case. If information is linked to uncertainty in this way, it is unusable in those cases. Moreover, if this point is relaxed somewhat, by not requiring that alternatives are known as long as a fixed set of alternatives exists, the problem remains that becoming aware of an alternative cannot be interpreted in terms of information. Nevertheless, receiving hypotheses or other types of alternatives can have important value for the practice of research. Having a hypothesis means being able to test it or use it.

A final shortcoming of Dretske's analysis of information as a measure for the value of communication is that it only values increases of knowledge or reductions of uncertainty. Other types of effects, such as the development of problems or undertaking actions cannot be incorporated in the measure. As such, that is not a shortcoming of Dretske's analysis. It means that Dretske's concept of information cannot be an adequate measure for the value of communication.[29] His notion is too restrictive to be widely applicable.

5.4.4. Information as meaningful data

In the previous sections we have seen that Shannon and Weaver (1949) developed an information-concept that is irrelevant for my interests and that Dretske (1981) developed an information-concept that is too restrictive. In this section I will turn to less 'extreme' interpretations of information. Although there is no single authoritative source in the field of organization science and information management to turn to for a definition of information, there seems to be a broadly shared opinion about the nature of information. In many publications information is defined as meaningful data (e.g., Tushman and Nadler 1978; In 't Veld 1986; Davis 1993; Checkland and

[29] But it should be noted that Dretske himself does not make that claim.

Howell 1998; Anand et al. 1998; see also Machlup 1983; Stamper 1985). However, both the term 'meaningful' and the term 'data' have been used in distinctive ways.

The term 'meaningful' can be interpreted in at least two ways. On the one hand it can refer to 'the conventional, common or standard sense of an expression, construction or sentence in a given language, or of a non-linguistic signal or symbol' (Loar 1995). In this way, 'Smith couldn't get on without his trouble and strife', means that Smith found his wife indispensable, and a bell in the metro means that the doors will close. Such descriptions of meaning can also be turned into statements including the phrase 'meant by': it was meant by the statement 'Smith couldn't get along ...' that he found his wife indispensable (Grice 1957). This type of meaning is tightly connected to understanding. On the other hand 'meaning' can refer to the usefulness of data.[30] This type of meaning refers to what signs mean to someone, what value they have for him. The following example may illustrate the difference between these two meanings of 'meaning'. If a newspaper headline states that Arsenal defeated Manchester United with 1-0, two soccer fans will understand this message in the same way. In the first interpretation of meaning, it has the same meaning for both of them. But if one of the two fans already knows this result and the other not, the message has a different value for them. For the ignorant fan it is useful, since he learns from it that Arsenal has won. For the other, this headline will be of little value. I will call the first meaning of 'meaning' just meaning, and this latter meaning of 'meaning' usefulness or value.

If we use the first interpretation of meaning, the working definition of information becomes 'data with meaning'. Machlup (1983) defends such a loose interpretation of information. But we have seen in the example of the soccer match that a meaningful message is not necessarily useful or valuable. This is acknowledged by Machlup, who stresses that the concept of information should not be restricted to useful, new or adequate messages. In this interpretation of information, it is probable that all useful communication can be interpreted in terms of information (assumption (1a)). All useful communication will probably be realized via 'data with meaning'. But instances of communication that are not useful would be considered as information transfer too. This interpretation of information does not distinguish between technical communication that contributes to the performance of research and technical communication that does not contribute. This type of meaning has nothing to do with the value of technical communication (contra assumption (1b)). It can be concluded that this first interpretation of meaning does not serve the information processing

[30] The first type of meaning is called non-natural meaning by Grice (1957). The second type of meaning is more associated with natural meaning.

approach. Therefore we should limit ourselves to the interpretation of meaning as usefulness.

In an interpretation of meaning as usefulness, the working definition of becomes 'useful data'. However, the concept of data can be interpreted in at least two ways as well (Machlup 1983: 646 describes some more distinctions). The term data is sometimes used for signs, symbols or messages that represent facts. But it is also used more generally to refer to a wider range of signs, signals, symbols and messages. For example, the greeting 'Hello!' is not a fact, but might be considered data in this second sense. This holds as well for meaningless or uninterpreted symbols like 'xpadscifdc'.

If we interpret information as useful facts we run directly into a problem. Many of the moves identified in chapter four are not descriptions of facts. A question, a hypothesis and an argument need not be descriptions of states of affairs. A central finding of the investigation of moves used in research-related communication was that much more is done in communication than uttering factual statements like 'The melting point of copper is 1356 degrees Kelvin'. So if we take information to mean 'useful facts', there are many instances of useful technical communication that would not qualify as information transfer. This interpretation of information would not support the line of reasoning of the IPA either.

The only option that is left is to interpret 'meaningful data' as useful signs, signals, symbols or messages. That overcomes the problem that moves other than descriptions of facts are excluded. MacKay (1956; 1961) develops an interpretation of this type. He identifies information with the effect on the 'total state of readiness' or 'orientation' of a receiver. This enables him to analyze questions and commands in terms of information too and to consider actions as well as an increase in knowledge as effects of information. Information becomes the capacity of messages to sort out any effect that is considered useful. In this interpretation of information, useful technical communication can indeed be interpreted as information transfer.[31] It also supports assumption (1b). But this is at the expense of theoretical depth. This interpretation would make the first step of the explanation of the IPA almost tautological: 'useful technical communication is useful since it conveys information' would become: 'useful technical communication is useful since it conveys messages that are useful'.

[31] However, in chapter seven the association with transferring alone will be questioned.

This does not yield much extra understanding. It may be perfectly legitimate to interpret information in this way, but it does not contribute to a real explanation.[32]

A further specification of usefulness might increase theoretical value but also increase the chance that such a specified interpretation of usefulness becomes too restricted. In fact, Dretske's analysis of information can be considered a specified interpretation of usefulness. We might for example state that its usefulness should lie in the capacity of messages to yield knowledge (e.g. Tushman and Nadler 1978: 614). But that raises the problems discussed in section 5.3. Or usefulness may be specified as the capacity to reduce uncertainty or ambiguity. Such an idea seems to be implied in the information processing approach. However, that would transfer the theoretical burden to the concepts of uncertainty or ambiguity. Therefore I will turn to an assessment of the use of those concepts in the next section.

5.5. Technical communication, uncertainty and ambiguity

In the explanation of the value of technical communication by the IPA, the step from information transfer to performance is mediated by the reduction of uncertainty or ambiguity (assumption (2)). According to the original formulations of the IPA by Galbraith (1973; 1977) and Tushman and Nadler (1978), the benefit of technical communication lies in its ability to reduce uncertainty. Galbraith (1973; 1977) defined uncertainty as a lack of information (see also Daft et al. 1987). A subject is uncertain when he is confronted with a question and a set of potential answers to which he assigns a subjective probability between zero and one. This is sometimes explained by the game of 20 questions, wherein subjects receive yes-no answers to questions about the identity of an unknown object (Daft and Lengel 1986: 556). Uncertainty is reduced when one or more options are rejected, when the subjective probability attached to one option tends to one and subjective probabilities attached to other options tend to zero. In the discussion of Dretske's information concept I already argued that such a notion of uncertainty cannot encompass the construction of problems, gaining options and undertaking actions. Further, uncertainty presupposes the existence of questions. But new knowledge may be acquired on topics one had no question about. Moreover, if, contrary to Dretske, uncertainty is interpreted subjectively, technical communication can even increase uncertainty. In chapter four I explained that subjective probabilities attached to the content of solutions may both be increased and reduced. When subjective probabilities are reduced from somewhere near one, uncertainty is increased. The construction or discovery of new problems is another

[32] When I use the term information in the remainder of this thesis, I will use it in this loose sense.

way in which uncertainty may be increased. This creates new questions. It can be concluded that not all useful communication reduces uncertainty.

Daft and Lengel (1984; 1986) recognized the limits of the concept of uncertainty explicitly. Based on Weick (1979), they argued that communication may indeed serve to reduce uncertainty, but that it may also serve to reduce ambiguity or equivocality. In a linguistic sense, ambiguity refers to an expression that has more than one meaning (Bach 1998). The word 'suit', for example, can refer both to a piece of clothing and a legal action. The concept of equivocality has been used in information theory, referring to incomplete information (Weick 1979; Dretske 1981). In Daft and Lengel's extension of the IPA, ambiguity[33] refers to the existence of conflicting interpretations. Ambiguity is associated with confusion, disagreement, lack of understanding, different frames of reference, ill-defined problems and a lack of objective data (Daft and Lengel 1984; 1986; Daft et al. 1987). Although they still refer to 'equivocal information' as well, ambiguity is predominantly used as a characteristic of a person or a group of persons. In that interpretation they state that communication can also serve to reduce ambiguity. Ambiguity is reduced when closure or consensus has been reached. Both the reduction of uncertainty and the reduction of ambiguity are assumed to yield an increased performance (Daft and Lengel 1986).

Taking in account ambiguity is an improvement upon the consideration of uncertainty alone. For example, it accommodates the development of consensus. It accounts for the fact that communication is not just the transfer of a one-dimensional good. Ambiguity cannot be solved by just gathering more 'bits'. It requires what Daft and Lengel (1984) call 'rich information'. However, it remains questionable whether all contributions that cannot be interpreted as uncertainty reduction, can be interpreted as ambiguity reduction. Take for example the reception of a new hypothesis or a rebuttal. In E153 (described also in Vignette C) Andrew presents results of his research to his colleagues of the polymer-processing cluster. He studied the processing of polymer with fibers. A few days later Frasier, another member of cluster, reacts upon these results. Frasier expresses doubts about the applicability of a theory used by Andrew. Andrew assumes particular material properties, but Frasier doubts whether those properties hold when the material has fibers in it. Andrew intended to write a report on his research, that he considered as finished. However, the doubts expressed by Frasier spur him to investigate the material characteristics. He decides to ask Pete, the expert on rheology, to execute some measurements to determine whether the actual rheological properties differ significantly from the

[33] Since Daft and Lengel, and later authors, use ambiguity and equivocality interchangeable, I will only speak of ambiguity here.

assumed properties. In a case like this, no uncertainty or ambiguity is reduced. It seems that different interpretations are born. It seems that ambiguity is created. Likewise, the creation of research problems is hard to interpret as the reduction of ambiguity. For example, certain research results made Frasier doubt a fundamental rheological principle. Since the falsification of that principle would be a very important discovery, he decided to explore this issue further. He presented his ideas in a Group Work Meeting. Frasier's ideas met resistance in this meeting. Jason criticized the simulation techniques Frasier had employed. Since Frasier respected Jason's expertise, he started to explore his critiques. In this case new problems were developed. Frasier could have chosen to follow orthodoxy, but he decided to scrutinize the basic principle. Jason's critique complicated the problem for him. A divergence of opinions had been created.

Some instances of technical communication reduce uncertainty. Other episodes reduce ambiguity. But there are also episodes in which no uncertainty or ambiguity is reduced. Some interactions may even increase uncertainty or ambiguity. Technical communication may develop conflicting interpretations, create confusion and create ill-defined problems. Nevertheless these instances of technical communication can be useful for the progress of research. This means that the second intermediary step in the explanation of the value of technical communication by the IPA is incomplete as well.

5.6. Concluding remarks

From the last two sections it can be concluded that the theoretical interpretation of the contribution of technical communication to industrial research is inadequate. Useful communication does not only reduce uncertainty or ambiguity. Further, the interpretation of technical communication as information transfer does not serve the explanation of the IPA. In some interpretations of information, the concept of information is not able to differentiate between useful and useless communication. This holds for Shannon and Weaver's technical interpretation of communication and for the interpretation of information as 'data with meaning'. Other interpretations of information make the concept of information too restricted to encompass all useful technical communication. This holds for Dretske's interpretation, an interpretation in terms of facts and the interpretation of information as the capacity to yield knowledge, reduce uncertainty or ambiguity. The one interpretation that makes the claim that the value of technical communication lies in the transfer of information true, is to interpret information as the capacity of messages to yield useful effects. However, that interpretation does not add much theoretical insight. Moreover, that would cut the link between information on the one hand and uncertainty and knowledge on the other hand, a link that is cherished among others by the proponents of the IPA.

A lesson that needs to be retained is that communication is not a process of filling an existing hole, of meeting an existing demand for a one-dimensional good. Technical communication contributes in diverse ways to industrial research practices. A reflection upon these diverse contributions has also showed that not all useful communication can be identified as knowledge transfer. For moves and effects that do not qualify as knowledge transfer but nevertheless contribute to processes of knowledge development, I proposed the concept of knowledge-conducive communication. In chapter seven I will return to the implications of this conclusion for the knowledge-based theory of the firm.

6.

ORIGINATION MECHANISMS

This is the second empirical chapter. It introduces a new concept: origination mechanisms. This concept refers to ways in which the content of communication can be accomplished. It forms the basis for an explanation of the contribution of technical communication to industrial research practices. The distinction of origination mechanisms is based on the observations that:

- *the content of communication sometimes exists before an interaction, but may be created within an interaction as well*
- *ego, alter and management can direct the process of selecting existing content or creating new content*
- *the selection of content or the development of new content can be oriented at a problem of ego, a problem of alter, a shared problem or not be problem-oriented at all*

These three dimensions together make up the concept of origination. Based on these three dimensions 24 logically possible origination mechanisms can be discerned. In the analyzed interactions, 16 of them were found. The body of this chapter describes and gives examples of each of these origination mechanisms. These descriptions show that each origination mechanism is associated with a limited set of moves and effects:

- *direct contributions are predominantly realized through orientations at a problem of alter or a shared problem*
- *the use of an origination mechanisms is not sufficient for an effect; several conditions need to be fulfilled for an effective application of an origination mechanism*

The concluding section of this chapter relates the concept of origination mechanisms to existing literature. I will argue that no comparable concept can be found in the literature and that the taxonomy of origination mechanisms enables to show a number of biases in the literature.

6.1. Introduction

The amount of things people can say is infinite. But only a fraction of what someone can say will be relevant for someone else. The content of communication matters, so much is obvious. It makes a difference whether one thing is said or something else. One message does not equal another message like one euro equals another euro. If a random message is chosen, the chances are very low that it yields a direct contribution to someone's work. Likewise, most of the things that can be said within a laboratory would at best only contribute indirectly to the work of a randomly chosen member of that lab. But normally people do not compose their messages at random and do not utter given messages to randomly selected interlocutors. The philosopher Grice (1975) has formulated a set of principles that people are supposed to follow in communication. Together they state: give the right quantity of relevant and unambiguous information of sufficient quality. But even if we presuppose that interlocutors have the intention to follow these principles, it is not obvious how they realize this. If we imagine two people completely unfamiliar with each other and each other's work, uttering useful moves is not straightforward. If they are in a social vacuum, they probably do not know what to say. In this initial position people do not know what the other knows or would like to know. Nevertheless, researchers succeed in technical communication that contributes to their practices. This chapter is born out of wonder about the ways in which researchers accomplish this. For the moment I shall call this a coordination problem.

In the literature on knowledge processes in organizations this coordination problem has popped up in several ways. For example some have described the goal of knowledge management to make sure that the right knowledge is available at the right place, at the right time. This has been labeled a logistics approach to knowledge management. When this analogy with logistics is pursued, a beginning of an answer to the coordination problem suggests itself. Like a logistics manager makes sure that the right products are at the right time at the right place, one might ask a knowledge manager to make sure that the right knowledge is at the right time at the right place. The coordination problem can also be stated as a problem of coordinating supply and demand. In the knowledge management literature several authors speak of knowledge suppliers and knowledge demanders (Hansen and Haas 2001; Davenport and Prusak 1998). Some individuals lack information or knowledge and others possess that information or knowledge. These suppliers and demanders of knowledge are supposed to meet in a knowledge market. This is another way of stating the coordination problem, but one suggesting a different type of answer. It evokes the image of a 'real market' on a market square, where buyers select among products offered by sellers.

In this research I did not follow these outlines of answers to the coordination problem, but started with empirical research. Therewith a couple of possible pitfalls were avoided:

- presupposing the existence of a supply, waiting to be transferred
- presupposing that it is easy to know available supply
- presupposing the existence of a demand
- presupposing that it is easy to know this demand
- presupposing that there is one type of coordination mechanism

One of the goals of the field studies was to observe the ways in which this coordination problem is solved in detail. In the description of the empirical results of the origin of moves I will not use the concept of coordination, for the reason that that concept already brings debatable assumptions with it. I will speak of the *origination* of moves. Origination refers to the way a particular move with a particular content is realized. The origination of moves turned out to be a multidimensional concept. It is made up of three dimensions. These dimensions concern the newness of the move's content, the source of determination and the orientation used in that process. When these dimensions are combined, a number of logically possible origination mechanisms can be created. In this way, it is an example of a profile-model type of multidimensional construct (Law et al. 1998). The different origination mechanisms are to some extent functionally equivalent ways of realizing contributions. Their functional equivalence lies in the fact that different origination mechanisms might yield the same result (Gresov and Drazin 1997). But it will also become clear that different origination mechanisms are generally associated with a particular set of moves and effects. Given the organizational relevance of the effects, the origination of moves turns out to be a valuable concept for organization studies and knowledge management. In this chapter I will first explain the dimensions of the concept of origination. Second, the types that occurred in the studied data will be described. This description will explicitly connect origination mechanisms with types of moves and effects.

6.2. Dimensions of origination

DIMENSION 1: EXISTING VERSUS NEW

Consider episode E1, one of the two-weekly group work meetings of the Group Buijs. After the discussion of some organizational issues, Luke is given the floor for a presentation of his research. He starts to tell about a stream of work that he has finished a couple of months ago. Then he tells about the problems he is currently working. He describes some of his first results and explains what plans he has for the future. During his presentation some of the attendants ask questions. These tempt Luke to explain more about his approach and results.

Now consider E37. In this episode the researcher Marc has a problem with the coating process of a certain object. During this process a particular pattern of irregularities is formed. He introduces this problem to Jason, who in turn asks for some details. Based on this, Jason forms a hypothesis on the cause of the problem: water might exist in the coating liquid. He also thinks up a solution for this problem. In this particular conversation, which lasted only for about five minutes, another thing happened too. Marc exclaims at a certain moment: *"I don't understand it, for it is the same liquid as I am normally using, and then there is no problem. Only now I am using it in black."* A couple of seconds later he goes on: *"But maybe ... the pattern is there all the time, but you don't see it. I might be seeing it now because of the dark color"*. Marc comes up with a supplementary explanation for his own problem, explaining the fact that he has not noticed the irregularities before.

I like to draw attention to one major difference between these two episodes. In E1 Luke tells about his own research. What he tells is not new for him. He just expresses his existing knowledge about his own research. In contrast, in E37 both Jason and Marc himself come up with new explanations. Their explanations of the coating irregularities did not exist before this interaction. The origin of the moves in which their explanations are expressed lies in a creative process. The content of the moves is newly developed. Within interactions, participants often actively think about the problems and solutions of themselves and others. This might result in the development of new ideas, which may be communicated within the interaction. This implies that communication does not only consist of telling another what one had already in mind before the interaction. What is communicated to others, often does not yet exist at the beginning of the interaction. Without the interaction, these moves would have been impossible to make.

Therefore, the first dimension describing the origination of moves is whether the content of the move already existed before the interaction or not. The distinction between an existing content and a new content can also be stated as the distinction between selecting and developing. Both expressions of this dimension will be used interchangeably. The origin of a move was coded as 'existing' when the move arises from a selection process either within the interaction or in anticipation upon an interaction. The origin of a move was classified 'new' when its content is developed anew in an active cognitive process, such as an act of problem solving, within the interaction or in anticipation upon an interaction. This development process needs not be conscious or intentional. A content that is new can be either completely new, or an existing idea used in another situation. It might be a new belief, experiment, question, argument etc. It might also be a new wish: 'I would like you to study this phenomenon'. The newly developed hypotheses etc. need not necessarily be new for the other participants in the interaction. Someone might invent a solution that the other already knew before.

DIMENSIONS 2: SOURCE OF DETERMINATION

The second dimension of the origination of moves concerns the source directing the selection of development of content. Many selections or developments are possible. Different actors may direct the selection or development. First, this can be ego, the person uttering the particular move. In this research speakers or writers are always identified as ego. Listeners or readers are always referred to as alter. This implies that within an interaction people may alternately be ego and alter. The second person who might determine the content is alter, the person the speaker is interacting with. This is the case when alter has posed a question to which ego responds. Alter may also be more indirectly directing, by introducing a certain topic. Third, it might be management. This is the case when a manager, group leader or projectleader tells someone to tell something to someone else. It can also be that it is not one of the persons directly directing the content, but that the person uttering the move is following a more or less implicit norm. This is the case when it is an acknowledged rule to tell something in a particular situation to someone else. Think for example of many administrative systems and management information systems in place in some organizations. These cases were also coded as being directed by management.

When the content of the move has been newly formed, it is very improbable, though not unconceivable, that someone else than ego is the source of determination. Alter might play a supporting role, for example by asking ego to reflect on something. However, there are also situations imaginable in which alter determines the process of development of an idea. This is for example the case in Plato's dialogues in which Socrates leads his interlocutors by strategically posed questions to a certain conclusion (it has been argued that teachers should mimic Socrates in his questioning style to help children and students in their learning process). Two of such cases have been found in this research.

Sometimes it is difficult to attribute the determination of content exclusively to ego, alter or management. For example, if alter determines by asking questions, he does not always specify what he wants in detail – he might be unable to do that. If alter would be able to communicate all specifications of desired knowledge, he would have that knowledge already. In the same way a supplier of knowledge cannot describe his knowledge fully without transferring it too. As Grant (1996b: 111) notes, while referring to the economist Arrow, the mere act of marketing knowledge makes it (partially) available to potential buyers. This problem can be resolved by second-order descriptions of knowledge (Pinch et al. 1996). The specification of what alter wants can be more ore less detailed. If it less detailed, alter leaves part of the selection process open to ego. We must conclude that it is a matter of degree in which alter, ego or management drives the determination of content. It might be said that their respective shares in the process add up to one hundred percent. Nevertheless, in this research I choose to work with a trichotomous classification. Using intermediate values would complicate the coding process too much.

DIMENSION 3: ORIENTATION

The third dimension is the orientation of the process of origination. This refers to the basis for selecting or developing. It concerns the object that the person who directs the selection or development has in mind. Possibilities are:

- an orientation at a problem of alter
- an orientation at a problem of ego
- an orientation at a shared problem
- no orientation at a particular problem

Take for example the case discussed in the beginning of section 6.2. In this episode both Jason and Marc come up with new explanations for a problem Marc has. The origination of the moves of Jason is new, directed by himself and oriented at a problem of alter, because it is Marc's problem he is thinking about. However, the origination of the Marc's moves is oriented at his own problem. He tells about his problem in order to get a reaction. Later on he develops a new explanation with regard to his own problem. Likewise, selection and development can be oriented toward a shared problem or not be oriented at a particular problem at all. In the discussion of the different origination mechanisms it will become clear how these orientations are instantiated.

6.3. Origination mechanisms

When the three dimensions are combined, a number of origination mechanisms can be distinguished. Three dimensions with respectively two, three and four values yield twenty-four logically possible combinations. Eight of these logically possible combinations did not occur within the studied material. These include for example the determination of the development of new content by management. It is imaginable that such a type of origination might occur, but only under very uncommon circumstances. In the following paragraphs the origination mechanisms that were found will be described and related to moves and effects. These discussions are both based on qualitative and quantitative analyses. As described in chapter two, the most time consuming analyses were qualitative. Qualitative analyses resulted in the concepts described in this section and chapter four. These qualitative analyses also yielded ideas about relationships between origination mechanisms, moves and effects. Quantitative analyses yielded support for and additional insight in these relationships. The quantitative analyses resulted in 227 fully coded (partial) episodes, stemming from 102 instances of technical communication. Interactions were divided into partial episodes when different origination mechanisms were at work within the interaction. This was the case most bi-directional communication. In the remainder of this thesis I will use the word episode to these (parts of) interactions that are characterized by a particular type of origination. Further details of these quantitative analyses are described in Appendix 5.

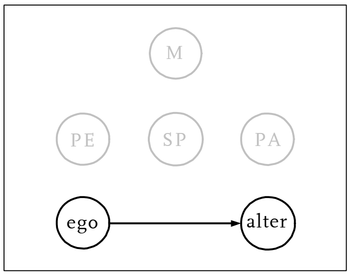
From Table 6.1 it can be read how many times each of the logically possible origination mechanisms occurred in the 227 episodes.[34] Sixteen did occur at least once, eight at least ten times. Table 6.1 further shows how these origination mechanisms are related to the main types of effects. Appendices 6 and 7 present cross-tabulations for origination mechanisms and moves, and origination mechanisms and subtypes of effects. These tables give the absolute number of times the combinations have occurred as well as the deviation from the expected number when all combinations are considered equally possible. This latter gives an indication for the relative importance of a combination, since it is corrected for the total number of times the codes in the row and in the column have been used. Appendix 8 summarizes the findings of Table 6.1 in terms of direct and indirect contributions.

[34] In section 6.4 I will interpret differences in frequency of occurrence of origination mechanisms.

number of cases		*change in problem-portfolio*	*contribution to a solution*	*activation after interaction*	*development of background knowledge*	*development of knowledge about others*	*activation within interaction*	*changing degree of consensus*	*total*
26	existing, determined by ego, not problem-oriented (p.133)	0 (-3)	1 (-6)	4 (-1)	8 (+5)	21 (+9)	9 (-3)	0 (-2)	43
18	existing, determined by ego, oriented at problem alter (p.135)	5 (+3)	8 (+4)	3	4 (+2)	6 (-2)	3 (-5)	0 (-1)	29
54	existing, determined by ego, oriented at problem ego (p.137)	2 (-5)	2 (-13)	9 (-3)	8 (+1)	38 (+11)	41 (+13)	1 (-4)	101
20	existing, determined by ego, oriented at shared problem (p.139)	5 (+2)	6	9 (+5)	2 (-1)	3 (-7)	10	2	37
8	existing, determined by alter, not problem-oriented (p.142)	0 (-1)	0 (-2)	0 (-2)	3 (+2)	8 (+4)	2 (-2)	1	14
16	existing, determined by alter, oriented at problem alter (p.140)	0 (-2)	11 (+8)	5 (+2)	0 (-2)	6	1 (-5)	0 (-1)	23
7	existing, determined by alter, oriented at problem ego (p.141)	0 (-1)	0 (-2)	0 (-1)	1	7 (4)	2 (-1)	0	10
5	existing, determined by alter, oriented at shared problem (p.141)	0 (-1)	3 (+2)	1	0 (-1)	2	3 (+1)	0	9
3	existing, determined by management, not problem-oriented (p.142)	0	1	1	0 (-1)	3 (+1)	2	0	7
1	existing, determined by management, oriented at problem alter (p.142)	1 (+1)	0	0	0	0	0	0	1
1	existing, determined by management, oriented at shared problem (p.142)	0	0	0	1 (+1)	0	0	0	1
3	new, determined by ego, not problem-oriented (p.148)	0	0	0	0	0 (-1)	3 (+2)	0	3
37	new, determined by ego, oriented at problem alter (p.143)	7 (+2)	20 (+10)	9 (+1)	0 (-5)	5 (-13)	17 (-2)	11 (+8)	69
12	new, determined by ego, oriented at problem ego (p.146)	0 (-1)	1 (-1)	0 (-2)	1	4	7 (+3)	2 (+1)	15
14	new, determined by ego, oriented at shared problem (p.147)	7 (+5)	6 (+3)	4 (+1)	0 (-2)	0 (-6)	4 (-2)	2 (+1)	23
2	new, determined by alter, oriented at problem ego (p.148)	0	0	0	0	1	2 (+1)	0	3
227	Total	27	59	45	28	104	106	19	388

Table 6.1: Origination mechanisms and main types of effects

EGO SELECTS, NOT ORIENTED AT A PARTICULAR PROBLEM (DIFFUSING)[35]



The first type of origination that I will discuss is diffusing. That label is used when ego selects existing content without an orientation at a particular problem. What is said is not meant to help anyone immediately. Nevertheless it occurs frequently (26 cases). This origination mechanism, diffusion, takes several forms. One of them is the reporting of finished research, for example by giving presentations, writing reports or publications and by holding a notebook that might later be used by someone else. Both within OGIR and the Group Buijs researchers were used to write reports and give colloquia within and outside their group. Also intranets can be considered as a form of diffusing, when the content of what is put on the intranet is determined by the author and is not oriented at a problem someone has at that moment. Diffusing does not only occur in such more or less formalized settings. Another form of diffusing is just keeping colleagues informed about one's research activities. For example, in E52 Jason is looking for Frank and finds him doing a mechanical strength test in his laboratory. Before Frank accompanies Jason to the meeting they both have to attend, Frank tells about this test and its current remarkable results. In a similar vein researchers tell newcomers about their work, and newcomers tell others about the work they are going to do. A third form in which this type of origination is realized is telling stories that are just considered nice to tell. An example of this is E206. Two researchers at OGIR have installed a new piece of measuring equipment that is in its specific form unique in the world. To celebrate this joyful occasion they invite all group members for a cup of coffee and a piece of cake. During this meeting one of them shows the apparatus to the group members and tells proudly about its features and about some first results obtained with it. Researchers often tell each other stories that are not immediately problem-oriented during lunches and coffee breaks. They tell about successes in the past and present, failures of others and peculiar research findings. When I was shadowing Frasier, he was working on an autonomous domestic product, nicknamed Monica. On his way to a meeting he stops by the office of a young female colleague, Judy, and shows how Monica moves around the room. I asked him why he showed the product to her. He replied: *"Oh, just because she thinks*

[35] The figures used to illustrate origination mechanisms should be interpreted as follows: "M" means management, "PE" a problem of ego, "SP" a shared problem and "PA" a problem of alter; the arrow from "ego" to "alter" represents a move; a dotted line toward one of the types of problems stands for an orientation at that problem; a dashed half-circle left to 'ego' refers to the development of new content; a dotted line from "alter" or "M" to "ego" stands for a determination by alter or management.

Monica is cute" (E124). A last example of diffusing is the Energy & Mobility News Alert sent periodically by one of the members of OGIR to a large number of subscriptors within Shell. In this newsletter he summarizes articles about new energy sources and uses that have appeared in journals and newspapers all around the world and provides hyperlinks to the complete texts of these articles. Appendix 6 shows that describing own activities, reporting own results and reporting about others are the moves that are typically associated with diffusing. This is clearly in line with the examples given above.

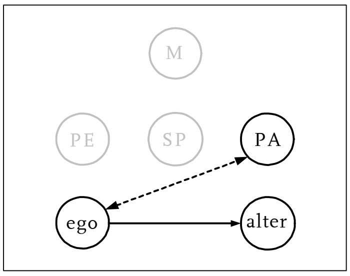
The fact that this type of origination is not oriented at a particular problem, does not mean that it is useless. It yields frequently indirect contributions to research practice (see Table 6.1). It scores high on the development of background knowledge, activating in interaction and especially on increasing knowledge about others. This is in the first place knowledge about the activities of others, but also about their knowledge, their problems, about literature and other interactions. These effects are not immediately useful but may be useful at a later point in time. Knowledge about knowledge of others can be used later to determine whom one may approach with a certain question. And knowledge about the activities and problems of others makes it possible to think along with them. Moreover, it seemed sometimes to be a social-psychological need for researchers to need to know about the work of their colleagues. Not knowing about the work of those surrounding them made them feel like working in a vacuum.

Diffusing did only one time result in a contribution to a solution. To many research problems there is no solution existing already, and, if nevertheless someone has it, it is improbable that it will be mentioned by chance. As Davenport and Prusak (1998: 91) write: "*When faced with a need for specific knowledge it would not be a sensible strategy to stand by the watercooler in hope of picking it up*". Nevertheless it is possible that diffusing leads to a contribution to a solution. It is possible to find answers in existing reports and other publications for example. In the single case in which diffusing led to a contribution to a solution Rick used the laboratory notebook of his predecessor to find an answer (E87). I assume that I would have found more cases like that when the focus of this research would have been more on the use of literature and reports and less on face-to-face interaction. I hypothesize that the effectiveness of diffusing in yielding direct contributions depends upon the following factors. First, it depends upon the possibility of pre-selection by readers or listeners. It is more effective to knowledgeably choose a publication from a library than to pick one at random. In the same way people might choose to attend a colloquium or not on the basis of an estimation of the potential value of what will be presented for them. Further, the effectiveness of diffusing depends upon the amount of potential readers or listeners.

The low chance of contributing immediately to a solution to another one's problem is increased when more people attend to what is said. Finally, the effectiveness of diffusing depends upon the similarity of the problems speakers and listeners are faced with. At a meeting of the Alcoholics Anonymous society, it is probable that just telling one's story, not particularly oriented toward someone else's problem, will be useful for listeners, while the chances are high that others face the same issues.

In chapter four I explained that I only studied research-related effects. But at this point I would like to mention that this type of origination has often an important social value. Telling stories about successes, failures and curiosities is fun. At lunch researchers often do not like to be busy with their day-to-day research. At lunch and during coffee breaks they often do not talk about research at all, but about the organization's management, politics, soccer, public transportation problems and their personal lives (such topics were not coded at all in my research). Telling about non-research related topics might also create trust. John states: "*If you start talking about a research-related topic at a coffee-break, then one after the other leaves the topic. Then you get three, four discussions at the same time. If that happens occasionally that is no problem. But for the group feeling it is better to talk about something everyone has something to say about. Like this morning, when we talked about XTC*" (NL 990921). Building trust and social cohesiveness might support later technical communication (see also Allen 1977: 196).

EGO SELECTS, ORIENTED AT A PROBLEM OF ALTER (PUSHING)



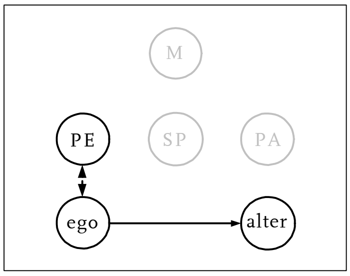
In the origination mechanism called pushing, ego selects existing content. To that extent pushing resembles diffusing. But contrary to diffusing, the selection process at the heart of pushing is oriented toward particular problems, namely one or more of the problems of alter. Pushing involves the belief that alter needs to know something, or that something might be useful for his research activities. A prerequisite for pushing is that one has at least some knowledge of the activities and problems of the other. A researcher uses this knowledge to determine what might be useful with regard to the problem of the other. In this way pushing differs from diffusing. In diffusing, a researcher just tells what he knows. He does not need too much knowledge about the people who he or she is talking to or writing for. Of course, some knowledge about (potential) readers or listeners is useful for presenting stories and reporting research. But pushing requires more cognitive work by ego.

The types of moves that are associated with pushing indicate specific instances of it. The six moves that occur most often in cases of pushing are describing experiments, describing findings or theory, describing technology, instructing, reporting about others and referring to persons (see Appendix 6). In E89 and E260 researchers tell about experiments that they have once used and consider potentially useful for alter. In E244 and E247 Karl instructs the newcomer Tony how to use a specific piece of measuring equipment. Karl said that he would need six weeks to show all the relevant options of the equipment once. In addition to 'describing experiments', these cases has also been coded with 'instructing'. Using the piece of laboratory equipment was intended to become one of the main tasks of Tony. Karl had used it for years until the work on a basic research project was stopped three years before. In this case Karl not only detachedly describes it, but also instructs Tony how he should use it. Another move associated with pushing is describing findings or theory. In E35, E74, E95, E267 and E274 researchers tell about theories and experimental findings that they consider relevant to the problems their listeners are working on. In E74 one of the researchers I have been shadowing, Jason, came looking for me at the room I shared with Richard. When he did not find me in, Jason started a conversation with Richard. Richard told about a theoretical problem that he recently started working on (Richard later confined me that he felt that the problem went a little above his head). Subsequently Jason, a superb theoretician, told about the factors that should at least be accounted for when solving this theoretical problem. Related to telling about theories or experimental findings is describing technology. In E37, after Jason helped Marc with a problem, Marc tells Jason about a technical solution that is used in coating processes for a certain class of coating deficiencies Jason is also concerned with. Jason said: "*Now he gives me a solution I did not ask for*". Actually, he considered the solution as a chemical technician's way of fighting symptoms. As a theoretical scientist he preferred to look for more fundamental solutions. Pushing also comes in the form of referring to other persons and literature. Regularly researchers inform each other about others who have relevant experience or work on related problems and suggest to get into contact with them. Likewise they tell about literature relevant to the problems of the other. Characteristical for pushing is that researchers do this without being asked to.

Moves stemming from this type of origination lead relatively more to contributions to a solution, changes in alter's problems and background knowledge, and relatively less to knowledge about others and activating within the interaction. That it leads more often to contributions to a solution and changes in problems results from the fact that the moves associated with pushing are selected with a focus on these problems. Nevertheless, not everything that ego considers useful for alter, will be considered directly useful by alter. An example of that is found in the rejection by Jason of the technological solution proposed by Marc, described above. But when it does not lead directly to a contribution to alter's problem solving, it might very well lead to an increase in relevant background knowledge. Although Jason will not directly use Marc's solution, he keeps it in the back of his head as a possible remedy for later problems.

An advantage of pushing above a pulled origination (see below) is that it might present ideas that alter is unfamiliar with, that alter has never thought about. An advantage of pulling above diffusing is that moves are focused at a problem of alter and therefore has a far bigger chance of being directly useful. In 12 out of 18 cases pushing yielded a direct contribution, whereas diffusing yielded only in 5 out of 26 cases a direct contribution (see Appendix 8). I hypothesize that the value of pushing in general increases with the knowledge ego has of the work of alter. A characteristic of pushing is that it might be interpreted as interfering with others' activities. Henry remarked: "*A real Nat.Lab.-er wants to interfere with everything*" (NL 990616). However, I did not come across a single example in which this interference was considered annoying.

EGO SELECTS, ORIENTED AT HIS OWN PROBLEM (REACTION-DEMANDING)

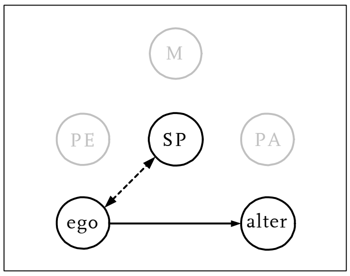


This origination mechanism occurred most frequently in the interactions studied. In almost a quarter of the coded parts of interactions ego selects what he says with an eye on one or more of his own problems. He says something to get a reaction oriented toward his own problem. Therefore this type of origination is labeled reaction-demanding. At first sight it seems a remarkable phenomenon that such a large share of communication is not oriented toward others but toward oneself. If we take a closer look this fact becomes understandable.

The most obvious form of reaction-demanding is asking questions one has with regard to a problem one is working on. Many instances of questions can be found. For example, in E72 Robin asks Jason: "*I have to divide parameter I by I_0. But I_0 is sometimes zero. Can I replace a zero by a one?*". Another example can be found in E226 where Bruce asks Geoffrey after the recipe to make a recently developed type of building material. In absolute terms reporting about own activities, describing own problems, describing own results and asking questions are the moves that most often originate in this way. Reporting about own activities, describing own problems and describing own results often go hand in hand. In E209 Malcolm tells in a large lunch-bag meeting about a new type of reaction they recently started working on. He uses no sheets but writes the reaction equations on the spot on a large sheet of paper. He goes on to say that they are looking for ways to improve the pace of the reaction, the process itself and the products of the reaction. Then he asks for suggestions from the audience. Other moves that score relatively high on this origination mechanism are showing and handing over publications. John showed for example a fractured optical disc to Peter in order to let him determine what caused the fracture. Sometimes reports or concepts of publications are handed over to alter to get a reaction. At the Nat.Lab. it is required that every manuscript intended to be published in a journal or presented at a conference is reviewed by two other researchers from the Nat.Lab. "*As they approve it, the chance that it is a bad piece of work decreases*" said John (NL 990714). Finally, it should be remarked that the difference between reaction-demanding (oriented at own problem) and diffusing (not problem-oriented) is not always very clear. In some cases, for example some presentations, ego is not really aiming at a reaction, but would welcome them anyway.

Moves stemming from this origination mechanism create the possibility that alter might give a reply focused on his problem. He gives alter something to think about. This makes reacting within the interaction the most frequently occurring effect of this origination mechanism. In more than seventy percent of the cases reaction-demanding leads to a reaction in the interaction, characterized by another origination mechanism. In some additional cases it leads to later communication (see Appendix 7). If a question was asked, these reactions are mainly of the type 'pulled origination' (see below). In that case the current ego specifies himself what reaction he desires from alter. If ego explains his activities and the problems he encounters in order to get a reaction, reactions will be more often of the type 'thinking along' (see below) and 'pushing'. In that case he leaves the later reaction of alter open. That places a stronger cognitive demand on alter. Not surprisingly, reaction-demanding also leads in two-third of the cases to knowledge about others. This knowledge is necessary to give a reaction. Furthermore it leads in some cases to an increase in background knowledge, since hearing about the activities and problems of others might result in knowledge that may be of later use. Reaction-demanding leads seldomly to a contribution to a solution for alter or a change in the problems of alter. In the two cases in which it brought about changes in the problems of alter, alter afterwards became involved in the problem ego told about.

EGO SELECTS, ORIENTED AT A SHARED PROBLEM

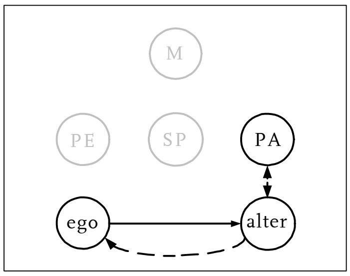


Some research problems are shared by two or more researchers. That means that each of them bears some responsibility for the problem. Researchers frequently work together in projects. Not all research problems in a project are shared. In virtually all projects there is a division of labor, which gives each of the project members his own sub-problems. But in projects there are also overarching questions that can be considered problems shared by the project members. Project teams at the Group Buijs and OGIR frequently consisted of a research scientist and a research engineer. Also in that collaboration, some of the problems are shared and others are the responsibility of one of them. At OGIR Geoffrey worked together with Arnold on developing a simulation of a process. This work consists of sub-problems that can be divided over three levels: questions with regard to the process itself, questions with regard to the structure of the simulation and finally the operational task of the programming of the simulation. Geoffrey told that the operational programming was the specific task of Arnold and that the questions regarding the process itself were his concern. They had a more joint responsibility for problems at the intermediate level (OGIR 010530). Another type of shared problem is the meta-problem of developing new research problems, new areas of research. At the Group Buijs and OGIR this could be seen as a joint responsibility of the group leaders and the researchers of a certain cluster. Sometimes it is a matter of degree whether a problem is someone's own problem or a problem shared by ego and alter.

The origination mechanism described in this paragraph consists in a selection by ego oriented toward such a shared problem. This origination mechanism is characterized by moves like suggesting a technical solution, describing findings and theory, describing own results, describing technology, hypothesizing and giving arguments. It scores relatively high on instructing. The four cases in which this move is used are interactions between a research scientist and an engineer, in which the research scientist orders the engineer to do something. In E86 Pete gives Rick samples of liquids and asks him to determine their rheological properties. In E166 David asks Richard to solve a theoretical problem. In this latter case this means that Richard has received a new sub-problem. Changing alter's problem-portfolio is one of the effects that result above average from this origination mechanism. The effect that scores particularly high is activating. Interactions between group members working on a shared problem often lead to new actions by one or both of them, such as new communicative actions, an intensification of thought on a particular subject and the execution of experiments. In general, the selection of content by ego oriented toward a shared problem leads often to direct contributions to research work and less to indirect contributions. For example, this type of origination leads only occasionally to new knowledge about others. This is not surprising, since researchers working closely together already know quite a lot about the activities, problems and knowledge of their colleagues.

ALTER SELECTS, ORIENTED AT A PROBLEM OF HIMSELF (PULLED ORIGINATION)

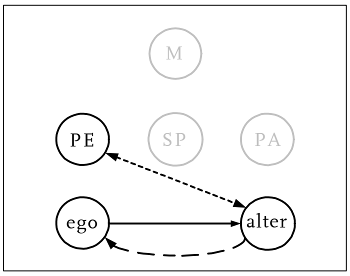
When alter determines the selection of content I characterize the process of origination as 'pulled'. The obvious way to determine a selection is to ask questions. The difference between diffusing, pushing and a pulled origination can be illustrated as follows. Imagine a traveler coming at a train station and going to the information desk. If the officer starts reading the train table from A to Z, or at random, this should be interpreted as diffusing.



When he induces from the fact that the other looks like a commuter that he has to go to the nearby big city, and gives information about the first train toward that city, the origination of that move should be interpreted as pushing. But when he gives an answer at a question of the traveler about a railway connection, this type of origination should be characterized as being pulled. A determination by alter will often be incomplete. First, it is psychologically impossible to determine completely what the other will say. Second, the specification of what one wants to know is not always worked out in detail. Four types of pulled originations can be distinguished, based on their different orientations. In this paragraph I will discuss pulled originations that are oriented toward a problem of alter.

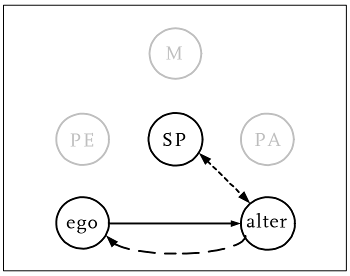
A selection of existing information on the basis of a question oriented at a problem of alter is very effective in yielding desirable answers. In thirteen out of sixteen cases it results in a direct contribution (see Appendix 8). Table 6.1 shows that a selection by alter oriented toward his problem yields a contribution to a solution in eleven out of sixteen cases. The effectiveness of this origination mechanism can be understood from the fact that in these cases alter knows quite well what he needs and who can provide that. The moves that are associated with a pulled origination are describing findings or theory, describing technology, referring to literature and instructing. In E234 Herman tells the heat transfer coefficient of a certain material to Geoffrey, after Geoffrey asked for it. In E167 Mary tells Rick the strength of the relationship between the viscosity and the concentration of a certain liquid. This is like asking factual information at the information desk at a train station (although Jason later on rejected the answer of Mary as being the textbook number, which did not apply in this case according to him). Correspondingly, people gave focused replies to questions about literature and technology. These moves also effected that alter started trying or using an experiment or a technical solution. This is shown by the fact that activating scores also above its expected value.

ALTER SELECTS, ORIENTED AT A PROBLEM OF EGO



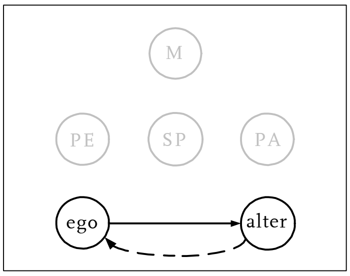
One of the paragraphs above described selections by ego oriented at one of his own problems. By explaining his problem and asking questions to others, he may try to evoke useful reactions. This might sometimes be supported by questions of alter. Alter might ask for explanation or more details in order to understand ego's problem better. If ego answers these questions on the basis of his existing knowledge, the origination of these moves can be characterized as a selection determined by alter oriented toward a problem of ego (coded seven times). These questions and answers mostly play an additional role. This type of origination yields only indirect contributions. It leads predominantly to an increase of knowledge about problems and activities of others.

ALTER SELECTS, ORIENTED AT A SHARED PROBLEM



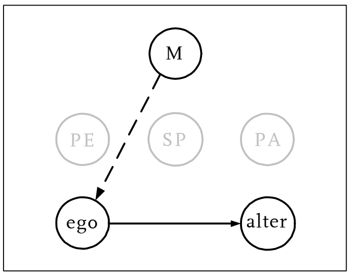
A selection process that is determined by alter may also be oriented toward a shared problem. Five instances of such a type of origination were coded. When two researchers are working on the same problem, it regularly occurs that one of them knows something that the other does not know. In the cases referred to by this type of origination one of them responds toward a question of the other about such a topic. For example, in E208 Robert asks Karl about a meeting he attended that was relevant for a shared problem of Robert and Karl. In E46 Rick tells that he has not yet done something he was supposed to do, after Jason asked him if he had done it already. Three out of the five cases in which this origination mechanism was found resulted in a direct contribution.

ALTER SELECTS, NOT ORIENTED AT A PARTICULAR PROBLEM



This origination mechanism is a response to questions that are not oriented at a particular problem. These questions are often posed out of interest in the subject matter. Some of them are elaborations on a specific point with regard to research ego was telling about. A quite different case is E80 in which Rick tells what he has done with regard to a particular research topic, after Jason asked to do so because he needed that information to check if the project meets a milestone. In one of these episodes I appear when I tell at lunch about the project of my new roommate, a newcomer at the department, after another group member asked me about that.

MANAGEMENT SELECTS



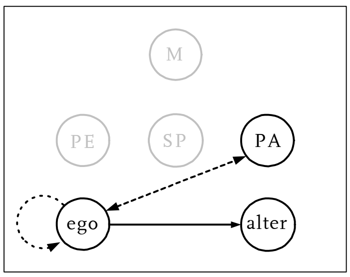
In the previous paragraphs we have seen that both ego and alter might steer the selection of existing ideas. A third possibility is that a selection process is more or less controlled by management, that management determines what someone should say or report to someone else. Table 6.1 shows that only 5 out of the 227 cases were steered by management. This small amount is due to the specific nature of research. In order to effectively steer the content of communication it is necessary that management knows what organization members know and what they need to know. But in research the researchers themselves are normally more knowledgeable with regard to their work then their managers, even when these managers have a research background too, like in the Group Buijs and at OGIR.

Management might control the content of communication in two ways. First, a manager or leader may directly order or ask someone to tell or report something to others. An example of this is found in E41. In this Group Work Meeting, David is asked by Maarten, the group leader, to tell the group about his trip to England. David tells about his visits to a university and two companies. He speaks about some of the technological developments observed and about the way one of these companies had organized the process of knowledge transfer from research to development. In another situation the head of OGIR asked Geoffrey to pass an order on to Karl (who was not present at the particular meeting). As Geoffrey does this, in E223, the selection of his message should not be interpreted as determined by himself or by

Karl, but as determined by management. Second, management may install or reinforce routines that determine the content of what is communicated. In some cases it is an organizational norm that something is told to someone else. In E234 Geoffrey goes to Herman, who is the projectleader of one of the projects Geoffrey works on, to report about some of his results. This can be seen as following an organizational norm to inform a projectleader about the progress of a part of the project. A combination of these two ways can be found in the cluster meetings at the Group Buijs (E35 and E92). Jason, the leader of the cluster 'coatings', starts these meetings with the remark "*Let's do a quick round first*". To the members of the cluster it is clear what this means: they are expected to tell about their activities of the last two weeks.

In the data one case was found in which the determination of the selection of existing content by management was oriented toward a problem of alter (E223, see above), one in which it was oriented toward a shared problem (E234, see above) and three in which it was not oriented at a particular problem (E41, E35 and E92, see above). The moves associated with them seem to be reporting about others, about own activities, knowledge, problems and results and about earlier interactions. Each of these types occurred too infrequently to say something about the effects associated with them. However, E35 shows a more general phenomenon that is worth mentioning. At one of the meetings of the coating cluster Patrick tells about his first endeavors to use a technical solution to improve the coating of optical discs. After hearing this, Jason exclaims: "*We could try that for the coating at the outside of television tubes too, if it is a way of improving tribological properties*". What Patrick said was not oriented at a particular problem. He just described his own activities. But Jason picked up the idea up and transferred it to another context so that it became a possible solution for one of his problems too. This is a case of serendipity, finding something you were not looking for. This form of serendipity is another merit of communication that is not directly oriented at problems.

DEVELOPMENT OF NEW CONTENT BY EGO, ORIENTED AT A PROBLEM OF ALTER (THINKING ALONG)



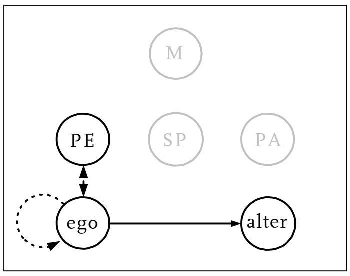
The previously discussed origination mechanisms are characterized by a selection of existing information. What is said was already existing. When communication is associated with concepts like information transfer, information exchange, knowledge transfer and knowledge flows it seems that everything that is communicated was already existing somewhere before it was uttered to someone else. That is not true. In 66 out of the 227 cases something was said that was more or less new to ego himself. That is, it was developed, consciously or unconsciously, during the interaction or in anticipation of it. I was first alerted to the fact that some things are constructed during the interaction when Richard went to Henry to ask for a heating element to use in measuring equipment (E26, described as Vignette A in chapter four). Henry rejects that option, but comes up with the idea to use ice to cool instead. Richard puts this idea into practice. He says: "*I went for something completely different. But they are so clever. I will ask him questions again.*" In 37 of these cases this new content was determined by ego, oriented toward a problem of alter (like in this one). This type of interaction might be called thinking along with somebody. It consists of temporarily applying one's knowledge to another one's problem.

This origination mechanism becomes clearer if we take a look at the types of moves that regularly follow from it. These are suggesting a technical solution, hypothesizing, suggesting an experiment, agreeing, rejecting, giving arguments, asking questions, questioning, concluding and redescribing and summarizing. These are most of the moves grouped as proposals and evaluations. In the discussion of the dimension existing versus new, E37 was used as an example. In E37, Jason comes up with an hypothesis with regard to the cause of a problem of Marc and suggests a solution to remedy this cause. In many more episodes hypotheses or solutions were constructed and suggested. In E209 Malcolm describes three questions he has with regard to the improvement of a new type of chemical process. This process is new to many of the listeners, but they come up with several suggestions how to improve the process. Some of the hypotheses and solutions are completely new, others variations upon existing ideas. In E41 Jason presents a specific coating problem he has been working on. Another group member, Chris, suggests: "*Can't you dry under vacuum?*". Of course, doing something in vacuum is not new, but as a possible solution in this case it is new for both Chris and Jason (but whether it is new for alter is irrelevant for classifying it as thinking along – that classification only refers to the origination of moves). Agreements and rejections are often classified as new too. For example, in E93 Pete talks Jason through a report he has written. Jason says: "*Right. That is beautiful!*" and "*Right, right, right …*". The word 'right' is not new for Jason, but his approval of the work of Pete is. Coming up with hypotheses or suggestions, agreements or rejections, is often accompanied by giving arguments. The content of arguments needs not be completely new, as long it is new to present it as an argument for a certain option. Two other types of moves often resulting from thinking along are asking questions and questioning. During interactions, frequently questions come up, such as: "*What is the scale unit at the left axis?" (E153)*, "*Do you have problems with instabilities?*" (E41), "*Does gravity have any effect here?*" (E40) and "*Why don't you add H_2 earlier, so that the ratio would be 2:1 at the beginning at the process?*" (E268). These are questions for explanation. Sometimes questions are of a more critical nature. Take for example the reaction of Jason at a presentation of Frasier: "*But isn't it possible to fit everything with eight parameters?*". Another example is the reaction of John to the presentation of a supposedly linear relationship: "*And both are linear scales? You have not smuggled away anything under log-log or something like that?*" (E155). Asking such questions is quite different from transferring existing knowledge. But it can be very useful, as the discussion of the effects of this origination mechanism will show. It forces the other to think about certain matters. This is in line with the finding of Okada and Simon (1997) that the number of requests for explanation is one of the determinants of the effectiveness of collaborative problem solving.

Thinking along with somebody is not restricted to single face-to-face meetings. Evaluating a report by somebody also classifies as thinking along, as long as some new ideas or opinions have been formed with regard to the report that are communicated later on. The development of something new by ego with regard to a problem of alter might also include doing an experiment for someone else. This could even lead to partly taking over a sub-problem.

Table 6.1 shows that thinking along scores high on contributing to a solution. In many cases it yields new technical solutions, explanations, observations and new arguments (Appendix 6). Most of all it leads to the formation of a degree of belief or to changes therein. That is understandable, because receiving a new hypothesis or solution is often accompanied by taking a stance toward that idea, and, moreover, changing the degree of belief in a solution might be the only effect of a part of an interaction. When the other agrees with something or rejects it, this might be considered a reason to change one's degree of belief in it. In E69 Luke shows Jason a graph of the characteristics of a filter he uses in a camera and asks whether he considers this filter good enough. Jason answers confirming. Because Luke considers Jason to be a near-expert in optical matters, this agreement is for Luke the reason to increase his belief in the reliability of the filter. Thinking along scores high on changing the degree of consensus too. Reaching consensus often implies forming an opinion, presenting and evaluating arguments and changing opinion. This frequently requires active thinking in interaction. Finally thinking along leads relatively often to changes in alter's problem portfolio. When Jason was asked in E40 whether gravity had any effect, this opened a new problem for him. He had not considered the possibility that it might have. So he decreased his believe in his current solution and started analyzing the effect of gravity. And indeed it proved to have a significant effect. This type of interaction has less effect upon background knowledge and knowledge about others. That does not mean that such effects are neglectible. These effects can also be valuable. Remember the remark of Richard after he got advice from Henry for the first time: *"I went for something completely different. But they are so clever. I will ask him questions again."* Richard's opinion about the knowledgeability of Henry changed as well.

DEVELOPMENT OF NEW CONTENT, ORIENTED AT ONE'S OWN PROBLEM (SELF-SUGGESTION)

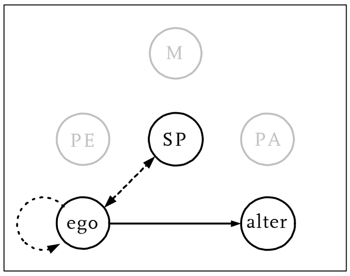


Like one can think about somebody else's problem, one can also think about one's own problem in technical communication. The need to explain one's own problem or the need to defend one's ideas stimulates to come up with new explanations, solutions, arguments and conclusions. Some researchers remarked that they purposefully talked to others, not to get a useful reaction, but to force themselves to structure their thoughts. This phenomenon is related to the so-called self-explanation effect in research on collaborative learning. Education scientists discovered that it is more useful for pupils to provide explanations to others than to receive explanations by others (Dillenbourg et al. 1996).

One example of self-suggestion was described in the discussion of the dimension existing versus new. In that interaction, E37, Marc comes up with an alternative explanation for the coating problem he has. Another example can be found in E53. When Robin is in the office of Jason, Jason asks the question whether it would be possible to show the working of a derotator on an overhead projector. It requires that a rotating and a fixed picture can be seen simultaneously. Jason himself starts drawing at a whiteboard and soon after finds that there is a simple way to do it. "*Brilliant*", he exclaims, "*that is something to show at the conference. I have to ask Gerald about that*". Moves that are associated with self-suggesting are giving arguments, agreeing and rejecting, asking questions, concluding, on the spot calculating or trying (in the example above) and expressing observations. An example of the latter is E173. Richard told Marcel about an unexpected optical effect that he did not understand. Together they take a look at it in Richard's laboratory. Strangely the effect does not show up again when they watch together (I witnessed that it was there before, and testified so to Marcel). They change lighting and the position of the sample and both express what they observe. The strange optical effect does not reoccur. Richard concludes that he does not understand at all what has happened.

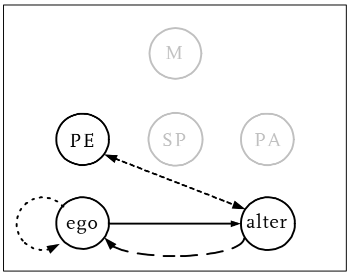
The overview of effects of self-suggesting presents a distorted picture. The table of effects only shows effects with regard to alter. But the defining characteristic of self-suggesting is that the main effect lies in ego, the person who speaks. The new content that ego utters is oriented toward his own problem. Table 6.1 shows that this origination mechanism mainly leads to knowledge about the other and to immediate reactions. The effects for ego himself can be partly induced from the moves uttered. That implies that self-suggesting leads to new solutions, new arguments, changes in opinion, new observations and new conclusions. It is necessary to remark that the effects of self-suggesting actually even go beyond that. It is by no means necessary that ego tells everything to alter about what he has thought up with regard to his own problem during an interaction. Many self-suggesting effects stay in the head of researchers, unnoticed by their interlocutors (and external observers like me).

DEVELOPMENT OF NEW CONTENT, ORIENTED AT A SHARED PROBLEM (COLLABORATIVE PROBLEM SOLVING)



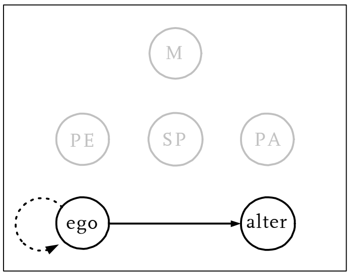
This origination mechanism can be seen as a mixture of the two previous types. An orientation at a shared problem is both an orientation at one's own problem and an orientation at a problem of alter. It may be labeled collaborative problem solving. Moves that are particularly associated with this type of origination mechanism are suggesting a technical solution, suggesting research activities, suggesting experiments, on the spot calculating / trying, expressing observations, asking questions and giving arguments. Indeed, these overlap with the moves associated with thinking along. In comparison with that set, agreeing, rejecting and giving arguments are underrepresented among the moves associated with collaborative problem solving. I cannot give an adequate explanation for that. This origination mechanism scores higher on on the spot calculating or trying and expressing observations. These moves evoke the image of two persons working together at the laboratory bench. An example of this can be found in E56. Three days before this interaction Jason and Rick have thought up a series of spin-coating experiments that they would like to carry out in a clean room. In E56 they are executing these experiments, together with two technicians. They inspect coated discs by the bare eye and under a microscope. They tell each other what they see. They perform scratch-tests and look at the resulting scratches under a very strong microscope, again telling what they observe. Collaborative problem solving scores particularly high on changing problem-portfolios and yielding contributions to a solution. It is evident that new solutions are developed during collaborative problem solving. Those results often lead to new questions as well. Each of the twelve instances of this origination mechanism led to a direct contribution.

THE DEVELOPMENT OF NEW CONTENT, DETERMINED BY ALTER, ORIENTED AT PROBLEM EGO (SOCRATIC TEACHING)



This is one of the more rare origination mechanisms. It only occurred twice amongst the coded episodes. But it is an interesting one. What happens is that ego comes up with something new, but that process is controlled by alter. It is comparable to the Socratic style of teaching, named after Socrates' style of debating: leading students or interlocutors with questions to the right answer. In E97 John asks Joseph whether a piece of measuring equipment of Joseph has certain characteristics. Joseph replies: "*What do you think yourself?*". "*I think 'yes'*". In E244 Karl teaches Tony how to use the Ultra High Vacuum equipment (looking like a miniature submarine). To use it one has to move a sample through the apparatus with a sort of remote mechanical joy-stick. This requires a very fine motoric skill. Dropping the sample would imply repair works for two weeks. Karl lets Tony play around with it to learn how it feels. In this example Karl is steering a learning process of Tony. When Tony does not know how to go on, and has drops of sweat on his forehead, he asks "*Should I give pressure?*". Karl answers: "*I really can't tell if I normally do*", and takes over. In proceeding he discovers that he indeed gives pressure and says so. A typical case of tacit knowledge.

DEVELOPMENT OF NEW CONTENT, NOT ORIENTED AT A PROBLEM



The three cases coded as the development of something new by ego, not oriented at a particular problem consist of the birth of new questions about other's research activities. These three cases lead to reactions in the interaction. Other forms of this type are imaginable and observed in cases not present in this quantitative analysis.

6.4. General results

This chapter started by wondering how researchers realize useful technical communication, given that the usefulness of possible messages is far from obvious. The previous section has described various mechanisms by which researchers effectuate technical communication. I described the moves and effects that are particularly associated with each of the origination mechanisms. In this section I will reverse the focus. In stead of 'looking forward' from origination mechanisms to moves and effects, I will 'look back' from direct contributions. This implies a shift from a more descriptive perspective to a more explanatory perspective, telling the 'story' of the realization of direct contributions.

Direct contributions are those effects of technical communication that are directly useful in the process of creating and solving problems. Direct contributions may be reached in three ways; (1) direct contributions are predominantly reached through an orientation at a problem of alter or a shared problem (see Table 6.2). In those cases ego says something that is directly useful for alter, because it was selected or developed with an eye on a problem of alter or a shared problem. These origination mechanisms include thinking along, pushing, collaborative problem solving and pulled originations oriented at a problem of alter. Origination mechanisms characterized by an orientation at one's own problem or by a lack of an orientation at a particular problem lead most frequently to indirect contributions.[36] Nevertheless, (2) direct contributions can also be reached when moves are not oriented at a problem of alter or a shared problem. Table 6.2 shows that origination mechanisms that are not problem-oriented or are oriented at a problem of ego do sometimes yield direct contributions as well. This can be through cases of serendipity – when ego tells something that happens by chance to be useful to alter. It can also be that alter is able to select from information that is communicated without an orientation at a particular problem, like when one finds a useful publication in a library. Finally, (3) direct contributions are also realized through self-suggesting and Socratic-teaching. In those cases ego thinks up new ideas while thinking on his own problem, possibly inspired by alter.[37]

[36] Likewise, new content is more likely to be directly of use than existing content. However, this can be explained by the fact that a large majority of the originations coded as "new" are oriented at a problem of alter or a shared problem. It is not the fact that content is new that makes it more valuable, but the fact that it is developed with an eye on a particular problem. However, within the originations oriented at a problem of alter or a shared problem, the development of new content has an irreplaceable value.

Focusing on the main source of direct contributions, an orientation toward a problem of alter or a shared problem, we can note the following. Both ego, alter and management can take care of this orientation. Table 6.3 shows that ego is most often the one taking care of this orientation. But a determination by alter is on average as effective as a determination by ego. Asking for needed information is as likely to yield a direct contribution as the selection or development of content by ego. If we finally focus on origination mechanisms characterized by a determination by ego oriented at a problem of alter or a shared problem, we can note that both the selection of existing content and the development of new content lead relatively often to direct contributions (Table 6.4).

number of cases	*origination mechanisms*	*direct contributions*	*indirect contributions*
72	oriented at problem alter	52	19
75	oriented at problem ego	13	51
40	oriented at shared problem	30	7
40	not problem-oriented	6	34
227		101	111

Table 6.2: Orientations and direct and indirect contributions

number of cases	*origination mechanisms*	*direct contributions*	*indirect contributions*
89	determination by ego, oriented at a problem of alter or a shared problem	65	17
21	determination by alter, oriented at a problem of alter or a shared problem	16	8
2	determination by management, oriented at a problem of alter or a shared problem	1	1

Table 6.3: Direct and indirect contributions for orientations at a problem of alter or a shared problem, distinguished for determinations by ego, alter and management

[37] These are underrepresented in the data, while these focus on effects on alter.

number of cases	*origination mechanisms*	*direct contributions*	*indirect contributions*
38	existing, determined by ego & oriented at a problem of alter or a shared problem	27	12
51	new, determined by ego & oriented at a problem of alter or a shared problem	38	5

Table 6.4: Direct and indirect contributions for orientations at a problem of alter or a shared problem, distinguished for existing versus new contents

The discussion of origination mechanisms raises questions about the choice for origination mechanisms. The origination mechanisms that I distinguished do not correspond in detail to cultural categories employed by the researchers studied. The taxonomy of origination mechanisms is not an ethnographic description of a part of the meaning-system of the researchers. Nevertheless, the dimensions underlying the concept of origination are to some extent recognized. For example, related to the dimension new versus existing, Jason remarked that he preferred brainstorm-like meetings above formal presentations (NL 990702). Researchers were aware of the effect of self-suggesting, and some intentionally talked about their research to others in the hope that that would help them in structuring their thoughts. In an early paper on the construction of TEA-lasers, Collins (1974) describes that researchers only responded to questions asked by visitors from competing organizations, but did not themselves determine content of communication, in order not to give away the most secret information. Differences between interactions captured by the concept of origination play a significant role in the reflective monitoring of actions by researchers. Researchers form their communication patterns to some extent intentionally. But this does not mean that communication is fully pre-planned. Interactions follow the logic of situated actions described by Suchman (1987). Researchers find themselves in a situation and respond to the options offered by those situations. For example, one may ask a question to somebody, because he happens to be nearby.

Researchers cannot employ origination mechanisms at will. For example, given the effectiveness of pulled originations oriented at a problem of alter, one may wonder why that origination mechanism is not used more often. One answer lies in the fact that origination mechanisms are not themselves sufficient causes of particular effects. Among others, certain cognitive preconditions have to be fulfilled. In order to ask a question with a reasonable expectation of a useful reaction, one needs to know who knows what. Furthermore, asking after a certain solution is constrained when one does not have a clear question (in contrast with that, herein lies the strength of pushing. By pushing alter can learn about options he did not know about). Another reason lies in the specific nature of working in a research environment. Researchers are set to work on problems for which it is assumed that no solution exists already. Otherwise, research would not be necessary. This implies that others cannot give such a solution when asked for. In that case ego may help by thinking along. Necessary conditions for the effective employment of directions by management are seldomly available in research. Management is not often knowledgeable enough to know of information that ego has that might be useful for alter. I hypothesize that in more formalized and centralized organizations, such as insurance companies and production departments, the amount of management directed originations will be much larger. This is supported by the remark of Spender (1996: 46) that bureaucracies assume that all knowledge necessary is available at the top of the organization. I will pay more attention to these cognitive pre-conditions in the next chapter.

These pre-conditions necessary for the effective employment of origination mechanisms help to explain the relative frequency in which origination mechanisms are used. If researchers indeed follow the communication principles outlined by Grice (1975), stating that people aim at giving the right quantity of relevant and unambiguous information of sufficient quality, they will employ origination mechanisms only when they expect them to have a useful effect. For example, when a thought arises during a presentation, people will have a tendency not to utter it when they do not consider it useful for the presenter. This explains the relatively low frequency of management-directed originations. The frequency of occurrence of origination mechanisms depends as well on other social and psychological factors. Ego may refrain from making a critical comment in order to save the face of alter. On the other hand, ego may be stimulated to make a critical comment if he expects that it will raise his own prestige. The Not-Invented-Here syndrome may play a role as well (Katz and Allen 1982). Researchers like to solve problems and get their prestige out of solving problems. Asking others might be perceived as a weakness. Above that, it might be a characteristic of researchers that they are a bit stubborn. Luke gave a humorous twist to this point: "*At school we have learned that it is not allowed to copy from others*" (NL 990609).

6.5. Confrontation with existing literature

With the concept of origination I contribute to the literature an empirically grounded overview of the possible ways to realize technical communication that contributes to industrial research. Types of origination are different ways to overcome the 'problem' that useful messages do not flow automatically from person to person. Heads of people are not connected like communicating vessels. Furthermore, origination mechanisms are associated with different moves and effects and contribute to an explanation of the effectiveness of personal communication. In this section I will defend the claim that a concept comparable to origination and origination mechanism does not yet exist. Moreover, I will argue that the concept of origination offers the opportunity to show biases in the existing literature. I will discuss three such biases later in this section.

In the literatures that I have reviewed in chapter one, no comparable concept can be found. The way messages come about is often taken for granted. The basic elements of the linear communication model are a source, an encoder, a message, a channel, a decoder and a receiver (Berlo 1960). The findings concerning the use of sources, channels and messages reviewed in chapter one have little to say about the genesis of a particular message. The same holds for the factors influencing technical communication and knowledge sharing summarized in Appendix 4. No systematic attention has been paid to the origination of messages. Only some fragmented insights can be found. For example, Hansen (1999) and Szulanski (1996; 2000) both point at a stage before actual communication, called 'initialization' by Szulanski and 'searching' by Hansen. However, their conceptualizations of this preparatory stage deal only with the second dimension of origination, namely the source of determination. They assume the source of determination to be alter. Someone in need for some knowledge searches for it and hopefully finds it. This second dimension has been described partially by other authors as well. Several authors make the distinction between pushing and pulling (e.g., Rosenbloom and Wolek 1970: 39; Langrish et al. 1972: 73; Holsthouse 1998; Fisher and Fisher 1998: 190; Mahe and Rieu 1999; Schulz 2001: 664). This distinction correlates with the distinction between a determination by ego and a determination by alter. A difference is that the push – pull dimensions may encompass both the origination of moves and the origination of interactions. The same person often determines these, but not necessarily so. Whereas an information seeker may initiate an interaction, the sender (ego) may determine the content of what is said. Further, at some scattered places in the literature the distinction between new and existing content has been mentioned (see below). Galunic and Rodan (1998) discuss another facet of the origination of moves. They searched for knowledge related antecedents of 'detection probability', the chance that the potential usefulness of knowledge of one organizational unit for another organizational unit, is detected. Galunic and Rodan recognize therewith the problem that it is not obvious how people possessing knowledge and people needing that knowledge find each other (Huber 1991), but do not describe the different mechanisms through which this can be realized. Different 'modes of obtaining information' that were distinguished by Myers and Marquis (1969: 83) correspond partially to some origination mechanisms, but their overview is far from complete, nor systematic. But such fragmented insights have not been integrated with other aspects into a single concept. As a result of that, no comparable concept has been employed in empirical research.

The integrated concept of origination enables us to identify fallacious assumptions and biases within existing literatures. I will discuss three such biases: that information supplies are pre-existing; that alter determines the content of moves on the basis of an existing need for information; and that this determination is oriented toward a particular work-related problem of alter.

To start with, much of the literature seems to assume that information or knowledge that is transferred was already existing before the interaction. In the general model of Shannon and Weaver (1949) that informs much literature on information and knowledge transfer, the first phases of communication are the selection and encoding of a message. In such a model there is no place for the development of new content. In the transactive memory studies (e.g., Wegner 1987) communication is equated with the retrieval of previously stored information. Likewise, the information seeking literature (Leckie et al. 1996; Anderson et al. 2001) speaks of retrieving information from information sources. The assumption that information is already existing waiting to be transferred is not frequently clearly stated in the literature. But it seems to underlie concepts like flowing, collecting and distributing, and the idea of information sources from out of which information can be derived. This is even more so for concepts like a 'two-step flow of information', referring to gatekeepers transmitting information from literature and other external sources to others within the organization (Allen and Cohen 1969). The idea that knowledge that is transferred exists beforehand also seems to underlie knowledge management publications. For example, one of the major reasons given for the importance of knowledge sharing is to avoid 'reinventing the wheel'. Nevertheless, some scattered remarks can be found stating that information can be created within an interaction. In a study of brainstorm-groups, Baker et al. (1967) make a distinction between ideas developed during brainstorm sessions and ideas existing already before those sessions. Hertzum and Pejtersen (2000: 773) write in an interpretation of engineers' preference of oral communication: "*Oral questions often lead to queries about the situation that gave rise to* *the question to provide the person being asked a more solid basis for interpreting and answering the question. In the course of the conversation the person asking a question may also encounter that it misses the real problem and rephrase it or ask additional questions. In this way, neither the question nor the answer exists beforehand, both are products of the communication process. Contrary to this, the wording of a document is frozen and does not adapt to the questions that cause people to consult it."* This remark seems to refer to the creation of new content in communication. The occasional use of phrases such as 'discussion of technical issues', 'consulting' (Allen and Cohen 1969), 'feedback' and 'critical evaluation' (Tushman 1978) in the literature on information processing might be read as acknowledgements of the fact that information may also be the product of communication. However, these authors do not make that explicit. Some more distant streams of literature are typically associated with the creation of new content within communication. We might for example think of literature about brainstorming (e.g., Paulus and Yang 2000), collaborative scientific discovery (Okada and Simon 1997), collaborative problem solving (Barron 2000) and collaborative learning (Dillenbourgh et al. 1996; Chinn et al. 2000). These streams of research study pairs or groups working on a problem together. Many of the moves in such discourses would be classified as 'new, determined by ego, oriented at a shared problem'. But, for the reason that the purpose of these processes lies in developing new solutions for shared problems, this literature does not explicitly recognize this as a specific type of origination. It should be noted that the word 'new' is used often in a broader sense. First it is used to refer to information that is recently created, but not necessarily in the context of communication. Second, the phrase 'new information' is sometimes used for information that is new to the receiver. But that sense of newness does not say anything about the origination of the information.

The concept of origination enables us to identify other biases in the existing literature. Although the distinction between pushing and pulling has been made frequently, several streams of research only focus on 'pulling', supposing that a person asking a question or needing knowledge determines communication. This is for example clear in the 'search and transfer model' of Hansen (1999) and the conceptualization of knowledge sharing by Szulanski (1996; 2000). According to Schulz (2001) the IPA is wholly based upon the 'pull' assumption. This bias is particularly present in literature on communication among scientists and engineers from an information seeking perspective (Leckie et al. 1996; Anderson et al. 2001). Also Ashford and Cummings (1983) and Hertzum and Pejtersen (2000) focus only on information and feedback seeking. Transactive memory studies focus on the retrieval of information based on queries by those in need of information (e.g., Wegner 1987; Bouwen 2002). But information is not only looked for. Information can also be brought to someone – even when there is no demand. Table 6.3 even shows that most direct contributions are not realized via the retrieval of existing information. The unwarranted emphasis on information pulling as opposed to pushing, is often accompanied by another bias. Authors seem to assume that information seeking stems from an information need relating to direct work activities. A basic assumption underlying the general model that Leckie et al. (1996: 180) constructed of information seeking by engineers and other professionals, is that the roles and related tasks undertaken by professionals in the course of daily practice prompt particular information needs. This means that the bias toward pulling is often accompanied by a bias toward an orientation at the problem of the person pulling. When the focus is on pushing, for example in Hansen and Haas (2001), this is often accompanied by the assumption that this is not problem-oriented at all.

In addition to the identification of biases in the literature, the concept of origination mechanisms enables localizing different streams of research within the space of possible origination mechanisms. Studies of collaborative problem solving and brainstorming typically focus on the development of new content, oriented toward a shared problem. The construction of databases and intranets concerns the origination mechanism labeled 'diffusing'. Studies of information retrieval focus on pulled originations and diffusing. Studies of the so-called 'self-explanation effect' concern the mechanism labeled 'self-suggesting' (Dillenbourg et al. 1996).

I conclude that the concept of origination is a contribution to the existing literature. Fragments of it have been recognized in previous literature, but these have not been integrated. Different studies have focused on what I would call particular origination mechanisms, without comparing them to other origination mechanisms. A comparable concept does not yet exist, while it proves to be an important factor determining the effects of communication. Moreover, it enabled identifying three biases or false assumptions.

7.

THEORETICAL REFLECTIONS

This is the second theoretical chapter. In this chapter I will discuss the role of knowledge processes and cognition in technical communication. On the one hand, this chapter evaluates parts of the knowledge management literature and the knowledge-based theory of the firm. On the other hand, the empirically grounded explanation of direct contributions to industrial research practices is extended. These two lines of thought are interwoven and mutually support each other. With regard to existing literature, I will conclude that:

- *in contrast with existing views, technical communication often involves the use and development of knowledge as well*
- *this finding actually strengthens the explanation offered by the KBT; the presence of other knowledge processes implies that other, more efficient, knowledge integration mechanisms are realized in technical communication than only the transfer of knowledge; however, these other knowledge integration mechanisms are not adequately described by Grant*
- *in technical communication a particular distribution of cognition is realized, which is characterized by a moderately strong integration of cognition; this cannot be explained by existing task interdependencies; this implies that the focus on the differentiation and integration of knowledge and cognition is a substantial addition to a focus on the differentiation and integration of tasks, and not just a semantical shift*

Concerning the explanation of direct contributions, the following conclusions will be drawn:

- *the application and development of knowledge in communication is a necessary condition for the effective employment of those origination mechanisms that are likely to yield direct contributions*
- *the integration of knowledge without being transferred makes that those origination mechanisms in which ego selects or develops oriented at a problem of alter or a shared problem yield direct contributions in an efficient way*
- *the integrated system of distributed cognition that is realized in these origination mechanisms makes that especially creativity and reliability are enhanced in an efficient way*

7.1. Introduction

In this chapter I will discuss the role of knowledge processes and cognition in the contribution of technical communication to industrial research practices. This brings us into the realm of the knowledge management literature in general and the knowledge-based theory of the firm in specific. While the conceptual reflections of chapter five were based on the taxonomies of moves and effects presented in chapter four, this chapter is based upon, and extends, the analysis of origination mechanisms.

First, I will describe the different knowledge processes involved in communication. These knowledge processes enable the effective use of origination mechanisms. In the knowledge management literature, communication is predominantly associated with transferring knowledge. However, observations at the Group Buijs and OGIR showed that more knowledge processes may be found in technical communication. The development and use of knowledge, two other central knowledge processes, play an important role in communication too. This means that this research appeals to reconsider the role of communication in the knowledge-oriented organization literature.

Second, based upon the analysis of knowledge processes in technical communication, I will evaluate relevant parts of the KBT. This will be done in section 7.3. The focus will be on the explanation of the value of technical communication for industrial research provided by the KBT. In this explanation technical communication is interpreted as knowledge transfer, and knowledge transfer as a knowledge integration mechanism. To evaluate this line of reasoning I will extend the description of the KBT presented in chapter one. Especially the different knowledge integration mechanisms distinguished by Grant will be described in more detail. I will argue that knowledge integration is indeed an effective concept to explain the value of technical communication – but differently as initially conceived. There are other knowledge integration mechanisms at work in technical communication than only knowledge transfer. These other mechanisms are more efficient ways of integrating knowledge. This makes the explanation of the contribution of technical communication in terms of knowledge integration even stronger.

In section 7.4, technical communication will be interpreted in terms of cognitive work. Talking of cognitive work in stead of knowledge integration and other knowledge processes has some advantages. Among others, this enables linking research findings to the concept of distributed cognition. In technical communication a particular distribution of cognitive work is realized. This distribution of cognitive work increases the creativity and reliability of research.

Finally, the analysis of the cognitive dynamics of technical communication can be used to shed light on a more general issue. In chapter one I noted that the mechanisms for integrating knowledge discerned by Grant were previously conceived as mechanisms for integrating tasks. The question was raised whether something is gained by focusing on the integration of knowledge and cognition as opposed to the integration of tasks. I will argue that it does. The integration of tasks has traditionally been conceived as coordination that is required by task interdependence. The concept of task interdependence is also invoked in the IPA and the literature on distributed cognition. However, I will try to show that the integration of cognition is not only driven by task interdependence. The presence or absence of strong task interdependencies does not explain the presence or absence of a strong integration of cognition. Integrated cognition is not only valuable in the presence of task interdependence. This supports the view that knowledge- and cognition-based theorizing is a substantial and not only a semantical development of the field of organization studies.

7.2. Interwoven knowledge processes in technical communication

I argued in chapter one that both the information processing approach and the literature on knowledge in organizations tend to equate communication with transferring. In the knowledge management literature, technical communication is first and foremost associated with knowledge transfer, or related concepts like knowledge exchange, flow, dissemination, distribution and sharing. In chapter five I have argued that not all useful communication can be interpreted as knowledge transfer. Some instances of technical communication are better described as knowledge-conducive communication. In that chapter I did not question the concept of transferring as the only cognitive process involved in technical communication. That is what I will do in this section.

Knowledge development, knowledge transfer and knowledge use[38] are often considered as the central knowledge processes (e.g., Coombs and Hull 1998;

[38] The phrase knowledge use and synonyms like knowledge application and knowledge utilization are normally used to refer to the application knowledge in actions (which may include communication). But in the 1970s and the 1980s a body of literature appeared with regard to knowledge use (Glaser et al. 1983; Menon and Varadarajan 1992; Hellström and Raman 2001) that interpreted the phrase 'knowledge use' more broadly. This literature concentrated on the use of research results. Distinctions were made between instrumental use, conceptual use and symbolical use of knowledge (Menon and Varadarajan 1992: 56). The symbolical use of knowledge refers to the use of research as a source of legitimization or persuasion. What is coined the conceptual use of knowledge, corresponds to some degree with

DeCarolis and Deeds 1999) Other knowledge processes are either synonyms, subtypes or less important processes. The concept of knowledge integration, which will be employed in the next section, is a specification of knowledge application. In the knowledge management literature, knowledge development has only been related indirectly to technical communication. For example, according to Schulz (2001) organizational units create knowledge first, and then 'broadcast' it to other units. Other authors claim that organizational learning occurs, or is broadened, when that what an individual has learned is transferred to others (Shrivastava 1983; Huber 1991; Kim 1993). Knowledge development is also placed in the aftermath of knowledge transfer and communication by Galunic and Rodan (1998), who see knowledge flows as a precursor for knowledge recombinations. By interpreting some instances of technical communication as knowledge-conducive communication in stead of knowledge transfer, I have already sketched a more direct link between communication and knowledge development. Latour (1987) defends a somewhat comparable relation between communication and knowledge construction. However, I will argue in this section that knowledge development plays an even more direct role in technical communication. Some of the roles that knowledge use plays in communication have already been acknowledged, but other crucial ways have been overlooked.

This study has systematically explored the central role of knowledge use and knowledge development processes in technical communication. The different ways in which knowledge is applied and developed in technical communication are summarized in Table 7.1.[39] Some remarks upon these processes were already made in chapter six, since most of these processes are associated with the origination of moves. The degree and way in which knowledge is applied and developed in communication differ for origination mechanisms. Different knowledge processes are preconditions for the effectiveness of origination mechanisms. In this section I will bundle remarks from chapter six together and expand upon them.

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what I have called the development of background knowledge. The instrumental use of knowledge refers to the application of knowledge in one's actions. In the knowledge management literature the concept is normally restricted to this instrumental sense (but, ofcourse, in the knowledge management literature it is not restricted to the use of research products in actions). I stick to that habit.

[39] These findings regarding knowledge processes do also stem from the grounded theory analyses. However, it proved to be difficult to code the different uses of knowledge as rigorously as done for origination mechanisms, moves and effects. Therefore these results are reported more qualitatively. Fortunately, some of the different uses of knowledge were also found in existing literature, supporting my qualitative analyses.

knowledge use	knowledge development
➢ using knowledge to interpret moves ➢ using knowledge to transfer it ➢ using knowledge of what one does not know, to ask questions ➢ using metaknowledge to contact right person, to select sources and to choose to attend presentations ➢ using knowledge about activities, problems and knowledge of alter to determine what might be useful for him ➢ using background knowledge to determine what alter needs or might be able to use ➢ using knowledge in developing knowledge	➢ developing suggestions for experiments, technical solutions and research problems, developing hypotheses, questions, doubts, arguments, evaluations (agreements, rejections) and conclusions, possibly inspired by what others say ➢ developing beliefs about what might be useful for someone else

Table 7.1: Knowledge use and knowledge development in technical communication

First, it has been observed frequently that receiving, interpreting and evaluating messages, requires the application of knowledge (Cohen and Levinthal 1990; Weick 1995; Goldman 1999). Another obvious type of knowledge use is using knowledge when transferring it. My concern with the application of knowledge goes beyond these types.[40]

In the previous chapter I explained that origination mechanisms do not cause effects by the very fact of being employed alone. Their effective employment is enabled by the use (and development) of knowledge. Those origination mechanisms that are characterized by an orientation toward a problem of alter are most likely to yield direct contributions. Such an orientation can be determined by alter. If its intended receiver initiates the transfer of information, for example by asking a question, I have spoken of 'pulling'. Pulling is not unproblematic. In the first place, it requires having and

[40] Technical communication involves a number of other ways of using knowledge. When communicating we use our knowledge of phones, computers or whatever medium we use to pass messages on to somebody (Daft and Lengel 1984). We use knowledge of social rules to be accepted as a member (Garfinkel 1967). We use knowledge of grammar to make well-formed or understandable sentences (Chomsky 1980). However, I will be not be concerned with these uses of knowledge.

being aware of an information need. To ask a question effectively, it is necessary to know what one does not yet know. One must have an idea of what it is that might fill the gap and be able to turn that into a question (see also Miyake and Norman 1979). This knowledge is not always present, which constrains asking questions. In episode E98 John, who has started a new research project recently, visits Jack. Jack is an expert in dust particles. Although John's project involves managing dust particles, he has few specific questions for Jack. He does not know yet what he needs to know. Therefore he just wants to gain some background knowledge by talking to Jack. In that way he might learn what kinds of questions could be asked about particles. The development of a question is already a cognitive achievement. In this research that has been exemplified by recognizing the development of research problems as a research-related effect and by recognizing the development of questions as the development of new content.

Effective pulling is enabled further by knowledge about the existence of knowledge and knowledge about persons possibly having that piece of knowledge. One of the researchers of the Group Buijs stated: *"If I encounter a problem, I will first walk around in my group. I will go to Frasier, Henry or Pete, to the person of whom I think 'he is most knowledgeable about it'. You know what your colleagues do! If I want to measure the thickness of a layer, I go to Patrick or Mitchell. Microscopy, that's Peter. Image processing, Paul. You ought to know that!"* (NL 990817). The importance of knowledge of the existence and whereabouts of knowledge has particularly been stressed in Granovetter's (1975) analysis of weak ties and in transactive memory studies (e.g., Wegner 1987; Hollingshead 1998b). Wegner (1987) called this knowledge about knowledge 'metaknowledge'. It is possible to extend one's own metaknowledge with the metaknowledge of others. At the Group Buijs and OGIR it happened frequently that the person who was asked a question did not have an answer, but was able to refer the information-seeker to a third person, by using his metaknowledge in turn. Chris, one of the members of the Group Buijs, claimed that he was able to find all relevant knowledge within the Nat.Lab. with no more than four telephone calls. In a previous chapter I reported that the Nat.Lab. had even installed an office called 'Expert Consult', specialized in aiding researchers in finding the right person.

Pulling is enabled by the application of knowledge about one's own information needs and the application of knowledge about who knows what. These cognitive activities serve one's own research problem. Pushing involves cognitive work that is oriented toward alter's research problems. In pushing, ego chooses to transfer some existing content to alter. This may consist of content alter has never thought about. By pushing, ego takes the cognitive burden associated with asking questions from alter. The selection of content oriented at a problem of alter is enabled by the use of knowledge about the activities, problems and ideas of alter. Based on that knowledge and his relevant technical knowledge, he may conclude that something might be useful for alter or that alter needs to know something. Take for example E165. In this episode Pete proposes Richard to show him some different printing techniques that he has studied. Pete knew that Richard had recently started as a research engineer on a project studying a new kind of printing technique. He considered learning something about existing techniques to be useful for Richard. In this case Pete used his background knowledge of printing techniques and his knowledge about Richard's activities to induce that knowing about those techniques would be beneficiary to Richard. It is imaginable that Richard would have come up with the same idea, and would have asked Pete to tell about the existing techniques.

Pushing and pulling are alternatives that might have the same results. But often one of two is complicated for a lack of relevant knowledge. Take for example E244. In this episode Karl teaches the newcomer Tony how to use UHV-equipment. In this episode Karl is predominantly pushing, telling what he considers necessary for Tony to know. In this case pulling is difficult because of Tony's lack of relevant background knowledge. Likewise pushing might be impossible for a lack of knowledge about the other's activities, problems and knowledge. Pushing and pulling might also be complementary. Five days after E244, Karl is still instructing Tony (E247). What is different by now is that Tony frequently asks questions. Since he had been instructed for about a week at that moment, he had gained the background knowledge necessary to understand what he does not know. This is consistent with the finding of Miyake and Norman (1979), that people who have a moderate understanding of the topic under study ask most questions. In this way pulling complements pushing, and enables fine-tuning messages by addressing remaining questions. Pushing may also complement pulling. In many cases alter is not able to pose his questions in much detail. In E13, for example, Richard wants to analyze pictures with Leica QWin, a computer program. He asks Paul, who happened to pass by but proved to be an expert with regard to the program, how to use Leica QWin. Such a general question is not enough to determine completely what Paul can say. Therefore Paul names some of the possibilities and asks Richard in which he is interested. This results in more specific questions by Richard, questions that he would have been unable to ask beforehand. Pushing may have an irreplaceable value, since pushing may involve telling about options that alter had never considered and yield insights where there was no question. Collins (1974) illustrates this irreplaceable value. Collins studied communication patterns between research organizations that were all building a TEA-laser. Collins found that these organizations did engage in communication, but they only answered questions. They did not select any content themselves, they told nothing beyond answering the questions. By that strategy they seemed cooperative, but managed to keep many crucial details secret.

A selection by the third possible source of determination, namely management, is enabled by knowledge about both ego and alter. A manager directing the content of communication needs to have a belief about the usefulness of some information for alter as well as believing that ego has that piece of knowledge. In many routine based organizations, this poses no problem. This is showed by the abundance of management information systems, workflow systems etc. But in research, managers often miss one or more of the relevant pieces of knowledge. They may very well be in short of knowledge on the specific topics that group members work on. This explains the low amount of episodes in which management directs the content of what is said.

The last type of origination characterized by the selection of existing content is diffusing. In diffusing, content is selected without an orientation at a particular problem. This does not require much knowledge. It only requires having the information that is communicated. But its effectiveness in yielding direct contributions depends partly upon the degree to which listeners or readers are able to choose whether to listen or read. Researchers use their expectations about what they might find in a meeting or publication. This is for example clear in library visits. Further, researchers may use their metaknowledge about meetings and colloquia to select those in which they expect that something useful may be said.

Technical communication does not only involve the transfer of existing information and the application of knowledge. In many cases information is created within an interaction. Due to the nature of research, many answers to questions do not exist ex ante. In those cases, others may still be of help by coming up with new content. This is the case in originations that are coded as 'new'. Among the things that can be newly developed in communication between researchers are suggestions for experiments and technical solutions, ideas for research problems, hypotheses, questions, doubts, arguments, evaluations (agreements, rejections) and conclusions. In few cases it is complete knowledge that is created. What is developed is most often a contribution to a knowledge development process. The resulting communication is not knowledge transfer but knowledge-conducive communication. The development of new content can be either oriented toward one's own problem, a problem of alter, a shared problem or not oriented at a particular problem. These contributions to a knowledge development process can come from all interlocutors present in an interaction. Ego and alter may interactively come up with new ideas with regard to the problem of ego or with regard to a shared problem. We can assume that active thinking about a problem within an interaction occurs more often than reported in Table 6.1. Active thinking does not always yield new insights and new insights are not always communicated to interlocutors. One type of colloquium held at the Nat.Lab. are DOVO's ('*Donderdagochtend Voordrachten*', 'Thursdaymorning lectures'), open to all Nat.Lab. members. Jason explained (NL 990702) that those lectures have such a large audience that it is not easy to give feedback or to ask a question. If ideas or questions arise, people might refrain from communicating them. Further it should be noted that active thinking within an interaction is not only tied to face-to-face communication. The cases involving the development of new content, do also involve the use of other media, such as telephone, e-mail and other written exchanges. For example, the review procedure followed at the Nat.Lab., in which new evaluations might be formed, is largely based on written communication. Knowledge development activities involve the use of knowledge. This includes using knowledge about one's own or alter's problem and using relevant background knowledge.

Knowledge development can also be found in the interpretation of messages. The uptake of messages is not restricted to the reconstruction of speakers' meanings. A hearer can use a message in a different way as intended. For example, in E35 one of the researchers of the Group Buijs is telling his cluster that he is planning to test whether the coating of optical discs can be improved by giving the surface a certain treatment first. When Jason hears about these planned experiments, he says: "*If that proves to work, we might try the same solution for television tubes as well*". By what he says, a researcher can inspire a colleague to come up with an idea, they both had not thought of in advance.

It can be concluded that communication does not only involve transferring, but knowledge use and knowledge development as well. This contradicts what is generally assumed in the literature on knowledge processes in organizations. These processes are interwoven in the practice of communication. This also shows that communication is interwoven with other research practices. Knowledge development takes place both within and outside communication. Furthermore, this section has provided more insight into the knowledge and knowledge processes that enable the effective use of particular origination mechanisms. The availability of the different types of knowledge enables and constrains the different types of origination. The origination mechanisms that are most likely to yield a direct contribution are characterized by an orientation at a problem of alter or a shared problem. The effectiveness of these mechanisms depends upon the application and generation of knowledge taking place in these originations. The origination mechanisms that are most likely to yield direct contributions, such as pushing, thinking along, collaborative problem solving and pulled originations, require the deepest cognitive involvement in communication.

7.3. Knowledge integration

7.3.1. Theoretical background

In this section I will return to the explanation of the value of technical communication by the knowledge-based theory of the firm, introduced in chapter one. The previous section argued that the contribution of technical communication depends upon the knowledge processes involved. The analysis of the different knowledge processes to be found in technical communication enables an analysis of technical communication in terms of knowledge integration. This is a central concept in the KBT. The explanation of the KBT has been sketched in Figure 7.1. First, knowledge management literature and the KBT predominantly interpret technical communication as knowledge transfer. Second, the major factor invoked by the KBT to explain organizational performance is the integration of knowledge (Grant 1996a; 1996b; 1997; 2001). In order to produce or develop a product, a broad scope of knowledge is necessary. It is often impossible for one person to possess all that knowledge (Tsoukas 1996; Becker 2001). To arrive at a sufficient level of expertise, individuals have to specialize (Demsetz 1991). The production or development of products therefore requires that the specialist knowledge of several individuals be integrated. In innovation the integration of knowledge has been associated with the recombination of knowledge resources (Kogut and Zander 1992; Galunic and Rodan 1998). Third, knowledge transfer is one way of integrating knowledge. However, it is not the most efficient knowledge integrating mechanism. "*Any system of production that requires each individual to learn what every other individual knows is inherently inefficient*" (Grant 2001: 147). That means that the interpretation of knowledge transfer as a knowledge integration mechanism has a dual nature. On the one hand it is an explanation for the value of knowledge transfer. On the other hand it states that knowledge transfer should be avoided. It is interesting to see what the improved insight in technical communication implies for the line of reasoning of the KBT. Therefore I will interpret technical communication in this section in terms of knowledge integration. This interpretation is enabled by the identification of different knowledge processes at work in technical communication.

It should be noted that the interpretation of knowledge transfer as a knowledge integration mechanism is not very common. Many authors leave the discussion of the importance of knowledge transfer at the observation that it prevents reinventing the wheel, the empirical observation that the transfer of knowledge benefits performance (e.g., Szulanski 1996) or a general discussion of the value of knowledge for organizations. Grant's interpretation can be seen as an attempt to further the theoretical understanding of the value of knowledge transfer.

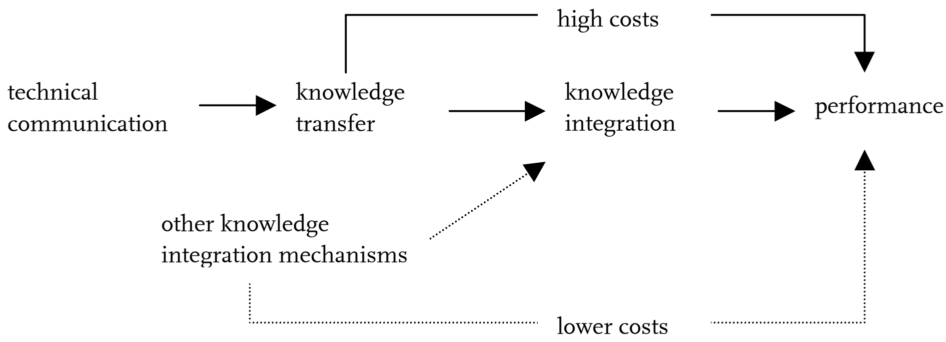

Figure 7.1: Explanation of the value of technical communication by the KBT

According to Grant (1996a: 375) the primary role of the firm is the integration of knowledge. Grant presents his ideas on knowledge integration as a way of dealing with the coordination problem in organizations. Knowledge integration refers to a coordinated application of knowledge. Grant uses a broader notion of knowledge integration than some other authors do. For Grant two pieces of knowledge have been integrated when they both come to bear on an operational process. Both pieces of knowledge have to be, directly or indirectly, applied to the operational process. Furthermore, this application of knowledge needs to be concerted, to be coordinated. The applications of knowledge need to fit each other, like two domino-pieces with the same number on their adjacent sides. This coordinated application of knowledge contributes to the performance of the process. Grant (1996a) emphasizes that the performance-enhancing effect of knowledge integration depends upon its efficiency, scope and flexibility. Others use a smaller concept of knowledge integration. For example, Okhuyzen and Eisenhardt (2002) consider knowledge integration to consist in the use and combination of pieces of knowledge held by individuals in collaborative problem solving or decision making. Information of several individuals should be combined explicitly in order to speak of knowledge integration (Okhuyzen and Eisenhardt 2002: 383). Grant does also speak of knowledge integration when knowledge is not explicitly combined. Grant distinguishes the following knowledge integration mechanisms:

1 - RULES AND DIRECTIVES

These are standards that regulate the actions of individuals. 'Direction' involves specialists in one area of knowledge issuing rules, directives and operating procedures to guide the behavior of non-specialists and specialists in other fields (Grant 1997: 451). Rules and directives can be interpreted as translations of a wider body of explicit and tacit knowledge on a subject into a limited instruction. This view of rules as a knowledge integration mechanism presupposes that the actor issuing a rule is the one who knows what is effective. He does not transfer all this knowledge, but only the results of this knowledge. For example, the constructors of an elevator know much about the mechanical properties of that system. Based on these properties they can determine the weight it can maximally bear. They translate that knowledge into a simple rule for the amount of people that may use the elevator at one time. Rules and directives are not very costly. "*Thus it is highly inefficient for a quality engineer to teach every production worker all that he knows about quality control. A more efficient means of integrating his knowledge into the production process is for him to establish a set of procedures and rules for quality control*" (Grant 1996b: 115). Grant's view of rules is quite optimistic. Everybody knows of rules, stemming from government, management, parents or 'specialists', which are considered as 'senseless' or made on the basis of incomplete knowledge. We might say, for instance, 'This rule is typically devised by someone behind a desk. He doesn't know how things work in practice'.

2 – SEQUENCING

This refers to the integration of knowledge by sequencing tasks. If task 2 has to be performed after task 1 has been completed, and person A knows how to execute task 1 and person B how to execute task 2, their knowledge can be integrated by letting perform person B task 2 after person A has performed task 1. In this way the necessary knowledge has been applied in a coordinated way in the production process.

3 – ROUTINES

Although Grant (1996b; 1997; 2001) describes routines as a distinct knowledge integration mechanism, it does not differ fundamentally from sequencing. According to Grant, routines can be applied in more complex situations, coordinating the application of knowledge by several individuals. The basic principle at work is the same as in sequencing: by creating routines, an individual only needs to know his part of the routine in order to realize a coordinated application of knowledge. For example, both at OGIR and the Group Buijs some measurements were executed by specialized persons of other groups. This can be considered as a routine (or as an example of sequencing): a researchers knows which measurements he needs so he determines what measurements should be done; someone else knows how to execute these measurements, so that person executes the measurements; the researcher himself knows best how to interpret the measurements, so he interprets them and uses them in his research. In this way, knowledge and tasks are 'co-located'. Each individual just has to know his part.

4 – JOINT PROBLEM SOLVING / KNOWLEDGE TRANSFER

In his (1996b; 2001) papers, Grant calls a fourth knowledge integration mechanism 'group problem solving and decision making'. Grant (1996b: 115) does not describe this mechanism in much detail. He calls it a 'more personal and more communication-intensive form of integration'. Okhuyzen and Eisenhardt (2002) limit the concept of knowledge integration to this mechanism. It consists of combining the knowledge previously dispersed over individuals in order to solve a problem or make a decision. In his (1997) paper Grant mentions 'transfer' as the fourth knowledge integration mechanism. It is unclear whether he intends this as a different mechanism than group problem solving. But also in his other papers he mentions transferring as mechanism for knowledge integration, be it a rather inefficient one. In transferring, the knowledge that is required for a particular task is not applied to that task by the person having that knowledge, but is transferred to the person executing the task.

Grant has based these mechanisms upon the task coordination mechanisms described by Thompson (1967), Galbraith (1973) and Van de Ven et al. (1976). Grant (1996b) argues that the first three mechanisms economize on communication. Costly communication is avoided by these mechanisms. For Grant these costs are particularly associated with the transfer of tacit knowledge. Grant (1996b; 2001) states that a basic need is to 'co-locate' knowledge and decision-making. Decisions should be made by those persons who have the relevant knowledge. Grant (2001) distinguishes two basic strategies. "*Co-location can be achieved in two-ways: decision making can be devolved to where the knowledge resides or knowledge can be transferred to the seat of decision-making authority.*" The first three mechanisms presuppose that knowledge is there were a decision is made or a task is executed or that the making of a decision or execution of a task is transferred to the person having the required knowledge. On the other hand, by the mechanism of knowledge transfer, knowledge is transferred to the place where a decision needs to be made or a task has to be executed. Since the transfer of knowledge may be costly, Grant claims that knowledge transfer is an inefficient knowledge integration mechanism.[41,42]

[41] By stating that knowledge transfer is an inefficient knowledge integration mechanism, Grant assumes that in the case of a mismatch of knowledge and task, it is cheaper to transfer the task than to transfer the knowledge. But he does not discuss this assumption explicitly. Moreover, in describing the other three mechanisms, he seems to assume that knowledge is already available to the person having to make a decision or execute a task.

[42] There are some important parallels here with the IPA. The two basic strategies discerned by Grant resemble the two basic strategies discerned by the IPA: reducing the need for information processing and increasing the capacity for information processing. March and Simon (1958) already discussed the same basic options to co-locate information and decision

7.3.2. Findings and reflections

I have argued in section 7.2 that technical communication involves not only transferring, but may involve various types of knowledge use and knowledge development as well. Since knowledge integration is the coordinated application of knowledge, these findings enable an interpretation of technical communication in terms of knowledge integration. If technical communication is interpreted as (only) knowledge transfer, the integration of knowledge depends upon the use of transferred knowledge by the receiver – for example by combining it with his other knowledge. The fact that there are other types of knowledge application at work in technical communication, undermines the interpretation of technical communication as just knowledge transfer. At first sight this may appear to be a weakness of the KBT. However, the concept of knowledge integration is able to accommodate this insight. It makes the explanation of the value of technical communication by the KBT even stronger.

Other types of knowledge application that may be involved indicate that there are other knowledge integration mechanisms at work as well – at least in some origination mechanisms. This can be best be illustrated by the origination mechanism labeled 'thinking along with someone'. In thinking along, ego develops some new content oriented at a problem of alter. This may involve a hypothesis, a suggestion for an experiment, an argument, a question or an evaluation. This involves the application of two types of knowledge. First, thinking along is enabled by knowledge about the problem of alter. It may be enhanced by knowledge about alter's activities in general and knowledge about alter's knowledge. Second, it is enabled by background knowledge about the topic at hand. Take for example E69. In this episode, Luke comes to Jason. Luke wants to use an infrared camera to gain images of the heat distribution in an optical disc. This camera needs a filter to measure at a particular depth. Luke had used the camera before to measure the heat distribution in glass, but he wants to employ it for the measurement of polycarbonate now. This requires a different filter. He has purchased a filter but got distorted pictures. He wondered whether the noise in the pictures was caused by characteristics of the filter. Since he is no expert in this matter he goes to Jason, who works at the same corridor. Jason is a near-expert in such optical matters. Luke shows Jason graphics with characteristics of the filter, provided by the supplier, and asks whether this filter meets the required quality criteria. Based upon his knowledge of optics in general and filters in particular, Jason concludes that the filter seems to be of sufficient quality. For Luke this rules out

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making. Both the IPA and the KBT see the transfer of knowledge and information as a way to diminish the gap between the information (or knowledge) that is needed and the information (or knowledge) that is available.

the option that his unsatisfactory results were caused by a bad filter. In this episode Jason arrived at a conclusion that he did not have before. This conclusion was enabled by his knowledge about Luke's problem. Moreover, his conclusion was enabled by his use of his specialized knowledge of optics. However, he did not transfer this knowledge of optics. Transferring all that knowledge about optics might have taken weeks. The application of that knowledge lasted less than five minutes.

In this episode, Jason's knowledge of optics is applied to the research task of Luke. Jason's knowledge of optics is integrated with the knowledge of Luke without transferring it (and without combining it in the sense of Okhuyzen and Eisenhardt 2002). Polanyi (1958) explains that all explicit knowing involves the use of a tacit foundation. Jason's application of his knowledge of optics involves the application of tacit knowledge. But by thinking along, this tacit knowledge needs not to be transferred. Thinking along in fact economizes on communication. This holds also for the other origination mechanisms that are oriented at a problem of alter or a shared problem, determined by ego.

If we return to the explanation of the value of technical communication by the KBT we note the following. The fact that technical communication does not only consist of the transfer of knowledge does not undermine the explanation in terms of knowledge integration, but strengthens it. In the line of reasoning represented in Figure 7.1. an arrow should be added going from 'technical communication' to 'other knowledge integration mechanisms' Origination mechanisms that involve the use of knowledge that is not transferred constitute a more efficient integration mechanism than the mere transfer of knowledge. If knowledge can be integrated without transferring it, this is more efficient. The concept of knowledge integration is therefore quite able to explain the value of technical communication. The IPA lacks the opportunity for such an explanation, since it only distinguishes between information transfer and no information transfer.

However, the knowledge integration mechanism at work in thinking along with someone does not fit the classification of Grant. In thinking along someone temporarily applies his knowledge to someone else's problem. It differs from transferring since some of the knowledge that is integrated is not transferred. It differs from directing in that is not a general instruction that is developed and there is no hierarchical relation between the persons involved. It differs from sequencing and routines since it is not a regularized pattern and knowledge is not only integrated by directly applying it. It requires communication too. It differs from joint problem solving, in the interpretation of Okhuyzen and Eisenhardt, since it is not a joint problem and not all knowledge that is applied is explicitly combined. On the other hand, there are similarities with each of the mechanisms as well. One reason for the fact that Grant's classification lacks the ability to accommodate this type of knowledge integration is that he has taken known task coordination mechanisms and has given a knowledge-based twist to them. His classification does not seem to be based on systematic empirical or theoretical grounds. Further, Grant's descriptions of the different integration mechanisms are not very precise. Grant (1996a: 384) himself notes that "*... much remains to be done at both the empirical and the theoretical level, especially in relation to understanding the organizational processes through which knowledge is integrated*". His overview certainly needs to be improved. My recognition of the knowledge integration mechanism at work in thinking along might contribute to such an improved conceptualization. The same mechanism, maybe to a lesser extent, is present in pushing. For the lack of a nice label, I will refer to this mechanism as the temporary application of knowledge toward an other one's problem. The development of new content oriented at a shared problem might be subsumed under the label 'joint problem solving', though it differs from the conceptualization of Okhuyzen and Eisenhardt (2002). In the research of Okhuyzen and Eisenhardt (2002) knowledge integration in joint problem solving refers to the combination of existing knowledge previously dispersed over individuals. When something new is developed oriented at a shared problem, not all knowledge that is used needs to be made explicit to everyone.

7.4 Distributed cognition

This chapter started out to examine the role of knowledge processes and cognition in the contribution of technical communication to industrial research practices. In chapter five I already argued that technical communication cannot be equated with knowledge transfer. Many instances of technical communication are better described as knowledge-conducive communication. Moreover, I argued in section 7.2 that the effectiveness of origination mechanisms depends upon the application and development of knowledge. Section 7.3 added the conclusion that the origination mechanisms characterized by a selection or development of content, determined by ego and oriented toward a problem of alter or a shared problem, integrate knowledge without transferring it (fully). That makes these origination mechanisms more efficiently. In the remainder of this chapter I will focus on cognition in stead of knowledge processes, in order to explain the contribution of technical communication further.

An explanation of technical communication in terms of knowledge integration has some shortcomings. First, the concept of knowledge integration treats knowledge as a resource (Okhuyzen and Eisenhardt 2002). Though knowledge integration is concerned with knowledge application, it does not focus on application but on the knowledge that is applied. That is, it takes a rather passive perspective. But it is not only knowledge that matters, but also 'knowing', what one does with knowledge. Second, the KBT uses an undifferentiated concept of knowledge. In chapter five I argued that the concept of knowledge transfer is too strong to describe all useful technical communication. Many instances of technical communication are better described as knowledge-conducive communication, communication that contributes to the process of developing knowledge. Likewise, it may not be knowledge that is integrated but mere beliefs. In order to deal with both issues, I want to interpret technical communication in terms of cognition. Cognition is an active concept, referring to processes (Garud and Porac 1999: xv). Knowledge is a more static concept. Cognition refers to perception, imagination, recall, problem solving, thinking and other processes going on in the heads of people (Neisser 1967: 4). I will use the phrase cognitive work to refer to the use of these processes in the practices of researchers. All the processes mentioned in section 7.2 can therefore be subsumed under the concept cognitive work. This concept makes it possible to relate observations on technical communication in industrial research to the literature on distributed cognition.

In those origination mechanisms in which ego does cognitive work oriented at a shared problem or a problem of alter, a certain distribution of cognitive work is realized. The concept of distributed cognition originated in the field of cognitive science (Hutchins 1991a; 1995; Salomon 1993), but the concept has soon been taken up in the field of organization studies (Weick and Roberts 1993; Tsoukas 1996; Madhavan and Grover 1998; Faraj and Sproull 1999)). Distributed cognition refers to the cognitive side of task execution. The idea of distributed cognition refers to the division of cognitive labor (Hutchins 1991a; 1995). Just like a particular organization of manual labor permits individuals to combine their efforts in ways that produce results that could not be produced by any individual alone, a particular organization of cognitive work enables groups and organization to reach cognitive goals that would be more difficult or impossible to reach individually. A central hypothesis concerning distributed cognition is that the performance of groups is not only influenced by the cognitive work of individuals, but also by the ongoing social organizing of the cognitive work of individuals. This theoretical claim is in line with the central claims of the knowledge-based theory of the firm (Kogut and Zander 1992; Grant 1996a; 1996b). The difference is that the focus is on the differentiation and integration of cognition in stead of the differentiation and integration of knowledge.

I would like to propose a concept that refers to a property of distributed cognitive systems: the integration of cognitive work. The functioning of a distributed cognitive system can be characterized by a degree of integration. The degree of integration of cognitive work refers to the degree in which cognitive work is oriented toward the same tasks. This idea of the degree of integration is equivalent to Weick and Roberts' (1993: 378) distinction between tightly and loosely coupled collective mind. It is related to the distinction between differentiated and integrated transactive memory systems (Wegner 1987). That distinction refers to the degree of overlap between knowledge possessed by individuals. The distinction I propose refers to the overlap between cognitive work.

The degree of integrated cognitive work is not intended to replace the dimension of knowledge integration, but serves as a complementary dimension. It differs in the following ways. First, the integration of cognitive work is a more active concept than knowledge integration. It refers to active processes, whereas knowledge integration refers more to the knowledge that is integrated. Second, the integration of cognitive work can be placed on a dimension from low to high. A high degree of integration of cognitive work refers to a large degree of overlap between the cognitive work of two or more persons. Although it might be possible to speak of a degree of knowledge integration as well, the knowledge integration mechanisms are functionally equivalent ways to establish knowledge integration. Third, whereas knowledge integration refers predominantly to the integration of different pieces of knowledge, the integration of cognitive work refers also to the use of knowledge that both people hold, such as knowledge of the problem involved.

The industrial research groups studied show a considerable amount of integrated cognitive work. Out of 102 full episodes analyzed quantitatively, 64 were characterized by an overlap of cognitive work and 38 were not.[43] In these cases at least one of the participants applied his knowledge to somebody else's problem or a shared problem, either to select messages or to contribute to knowledge development. These interactions indicate that the research groups function as a distributed cognitive system. The cognitive work required to solve research problems is performed by more than one person. In this respect the research groups resemble distributed cognitive

[43] Whereas the quantitative analyses presented in chapter six refer sometimes to parts of instances of technical communication, these numbers refer to full episodes. The total number of full episodes is 102, whereas the total number of (parts of) episodes is 227 (see Appendix 5). An episode is counted as exhibiting integrated cognitive work when at least one of its parts shows an origination mechanism in which content is selected or developed by ego or management with an orientation at a problem of alter or a shared problem. That means that I coded this dimension indirectly. I associate specific origination mechanisms with integrated cognitive work on the basis of the analyses of section 7.2. This means that the coding on this dimension is less reliable than the coding on origination mechanisms, moves and effects.

systems that have been studied previously, such as navigation teams (Hutchins 1995), cockpit crews (Weick and Roberts 1993; Hutchins and Klausen 1996) and software development teams (Faraj and Sproull 2000). But not all interactions studied show integrated cognitive work. Examples of these are non-interactive presentations, information transfers that are initiated by the receiver and stories that are not oriented toward a particular problem. For instance, in E206 (described as Vignette B in chapter four) Karl has invited the other group members for a cup of coffee and a piece of cake to celebrate the fact that he has ordered and received an advanced piece of measuring equipment. Karl shows them the installation and tells about its features. In this case there is no overlap in cognitive work. Although the research groups studied show a considerable degree of integrated cognitive work, this degree is probably lower than in the case of a cockpit crew.

Integrated cognitive work can have several advantages. Even persons with a relatively comparable knowledge base may come up with additional hypotheses (Okada and Simon 1997). Coming up with new ideas and questions is a creative process that has unpredictable properties. Existing knowledge might even hinder creative processes. The two researchers who discussed their new research problem during a lunch meeting with a group of colleagues (E209), told afterwards that they did not tell about the solutions they were already considering in order to prevent narrowing their colleagues' focus. In the second place, cognitive work that is oriented at a problem of alter or a shared problem can yield higher degrees of reliability. As Thagard (1997) notes, it is often easier to identify mistakes in the work of others than in one's own work. An example of the increase of the reliability of research outputs is the review procedure at the Nat.Lab. Manuscripts that will be presented in an external forum have to be checked by two other researchers, not involved in the project. Researchers at the Group Buijs explained that this was meant to ensure that the content meets certain standards of quality. I hypothesize that these advantages are reached in a time-efficient way. Compared to the time a researcher himself spends on a research problem, others can come up with additional ideas, questions, arguments or evaluations in a relatively short period of time. By letting people think along occasionally, the knowledge of more persons can be applied to one's problem, without necessarily loading those others with other activities involved in the research. Einstein is sometimes quoted as having said that scientific research is ten percent inspiration and ninety percent transpiration. Thinking along with someone enables using the inspiration of others without bothering them with the transpiring work. A different type of advantage of thinking along with someone is the following. In the knowledge management literature we often find the warning that professionals are reluctant to share their knowledge, since their knowledge is their most valuable resource

(Davenport et al. 1992). Thinking along is less threatening in that respect. In thinking along much knowledge is used, but only a fraction of it is given away.

The distributed cognitive aspect of industrial research is both structured and dynamic. Structure arises when, in the course of time, several instances of integrated cognitive work are undertaken. For example, at a certain moment Henry became worried about a young colleague, John, who was working at the same corridor on very different project. Henry thought that John was postponing experimenting too long. Henry mentioned this to John and started interfering more with his work. In later interactions he suggested possible ways to execute the experiments that he considered necessary, showed some existing facilities and introduced him to other persons who might be helpful. At the Group Buijs, the creation of clusters of researchers has yielded more continuous relationships. A prolonged application of one's knowledge to another one's work may eventually turn into taking over a part of the work of the other. In such a case a research problem turns into a shared problem, into interrelated sub-problems. On the other hand, the distribution of cognitive work is dynamic. What knowledge can be applied to what task differs over time. Furthermore, thinking along with someone and pushing need to be continuously enabled by communicating about activities, problems and knowledge. Many of the interactions that were classified as having no integrated cognition contribute in this way to the functioning of the research groups as distributed cognitive systems. By giving and attending presentations, people do not only learn about new results, but they also learn about the problems the presenter works on and the expertise he or she has. Many interactions seem to have learning about others as their prime goal. I documented in chapter six that the most frequently occurring effect of interactions is learning about the activities, problems and knowledge of others. Researchers purposefully tell about their problems and activities and ask others about their problems and activities. This is the value of communication that is not oriented at a particular problem. Chris said: *"I do not know what the common opinion is about me. Maybe they occasionally think 'my goodness, he is only walking around'. Yeah! But if I am just chatting somewhere, that chatting is purposeful: to stay informed about what my colleagues know!"* (NL 990817). This is hard to understand for those who consider information primarily as a means to solve one's own problems (e.g., Leckie et al. 1996). But this learning about others typically enables asking for help and helping others in the future (see also Faraj and Sproull 2000). What is accomplished is a continually evolving system of distributed cognition. Integrated cognitive work is a collective accomplishment that should be enabled over an over again.

7.5 Integrated cognitive work and task interdependence

7.5.1. Theoretical background

In this final section I will relate the integration of cognitive work to a well-known dimension in the field of organization studies: task interdependence. This confrontation shows that integrated cognition cannot be understood solely as a response to task interdependencies. But it sheds some light on broader questions about the importance of knowledge- and cognition-based theorizing in organization studies as well.

The differentiation and integration of tasks is a problem that has since long taken up a central place in the field of organization studies (March and Simon 1958; Thompson 1967; Galbraith 1973). The way tasks are differentiated might yield various kinds of task interdependencies. Task interdependence is the degree to which a subunit depends upon the performance of other tasks to perform its own task effectively (Tushman and Nadler 1978: 616). Thompson (1967: 54) distinguishes three types of task interdependence: pooled interdependence, sequential interdependence and reciprocal interdependence. Two organizational units are pooled interdependent when each part renders a contribution to the whole and each is supported by the whole. Units Y and Z are sequentially interdependent when unit Z can only perform its task after the successful completion of the task of unit Y. Reciprocal interdependence refers to the situation in which output of one unit becomes input for another and vice versa. Van de Ven et al. (1976: 325) add a fourth type of task interdependence: team interdependence. This refers to situations in which work is undertaken jointly by unit personnel who simultaneously diagnose, problem-solve and collaborate in order to complete the work. According to Thompson (1967) and Van de Ven et al. (1976) team interdependence presupposes reciprocal interdependence, which in turn presupposes sequential interdependence, which in turn presupposes pooled interdependence. From pooled interdependence to team interdependence, these types consist of an increasing degree of task interdependence. These task interdependencies create a need for coordination. According to Thompson (1967), pooled interdependence should be coordinated by rules and standards, sequential interdependence by planning and reciprocal interdependence by mutual adjustment. Team interdependence should be coordinated by scheduled and unscheduled meetings (Van de Ven et al. 1976).

I will explain below that the IPA, the KBT and the literature on distributed cognition relate technical communication directly or indirectly to task interdependence. Therefore it is interesting to know how the integration of cognition relates to task interdependence. Both the dimension of task interdependence and the dimension of integrated cognition can be dichotomized into a 'strong' and a 'weak' pole. If these two dimensions are combined, a two-by-two matrix can be constructed (see Figure 7.2). One may ask whether integrated cognitive work occurs as a response to task interdependence. Although none of the theoretical streams mentioned argue this explicitly, such a claim might be advanced on the basis of these literatures.

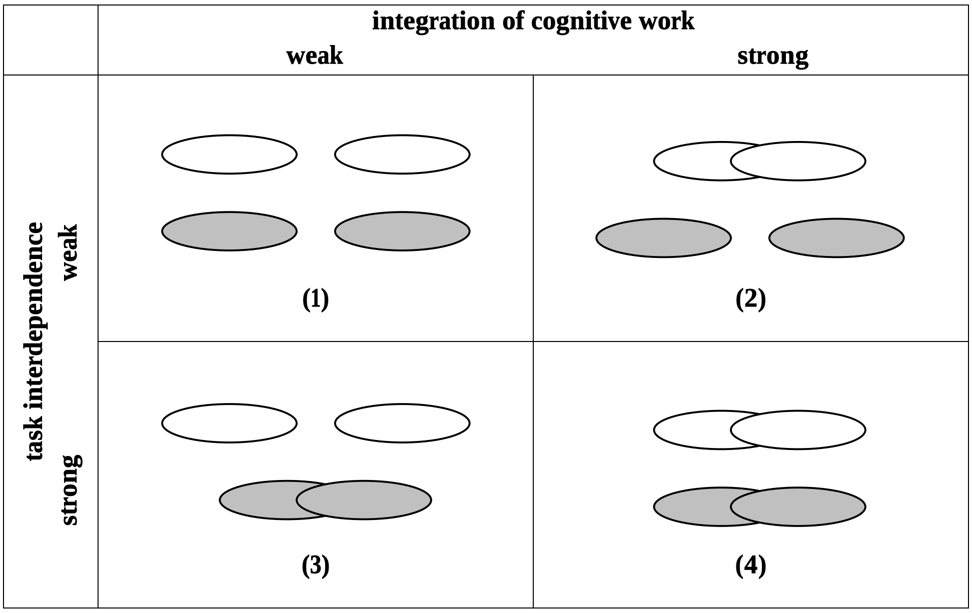

Figure 7.2: Task interdependence and the integration of cognitive work (white areas refer to the cognitive work of researchers and grey areas to their actual research tasks).

In previous chapters I explained that the IPA invokes task interdependence as one of the factors determining the need for information processing. The IPA interprets the four coordination mechanisms in terms of information processing. From rules and standards to interpersonal meetings, they exhibit a higher information processing capacity (Tushman and Nadler 1978). A higher degree of task interdependence requires more information processing and therewith more interpersonal information processing (since that coordination mechanism has the greatest capacity for information processing). Formally, the IPA does not say anything about the form this information processing should take. Nevertheless, Tushman and Nadler (1978) state that task interdependence typically asks for joint problem solving.

Grant's (1996b; 1997; 2001) knowledge integration mechanisms have been modeled on the task coordination mechanisms described by Thompson (1967) and Van de Ven et al. (1976). Grant gave a knowledge-based twist to these four coordination mechanisms. His fourth knowledge integration mechanism, joint problem solving / knowledge transfer is a modeled on the mechanism Van de Ven et al. (1976) proposed to coordinate a high degree of interdependence. The most interactive form of knowledge integration, the one with the highest degree of integrated cognitive work, is based on the mechanism proposed for the highest degree of task interdependence. Nevertheless, Grant (1996b: 114) suggests that technology and task characteristics do not determine the need for a particular knowledge integration mechanism. That would imply that the integration of cognition is (partly) independent from task interdependence.

Weick and Roberts (1993) link two corresponding dimensions: the coupling of tasks and the coupling of collective mind. They studied tightly coupled technological systems and argued that such interdependent tasks should be accompanied by tightly coupled collective mind (cell (4)). Other studies presented in the literature on distributed cognition also focus on groups executing tightly coupled tasks, such as navigating, flying an airplane and software development (Hutchins 1995; Hutchins and Klausen 1996; Faraj and Sproull 1999). They show how such systems with interdependent tasks are often accompanied by an integrated system of distributed cognition. Weick and Roberts (1993) argue further that tightly coupled tasks executed without highly integrated cognitive work, cell (3), are liable to failure.

In the next section I will interpret the interactions studied at the Group Buijs and OGIR in terms of these two dimensions. I will limit myself to those interactions that show integrated cognitive work. I will show that the processes associated with cell (4) were indeed found in my research. However, many other interactions seem to be located in cell (2). They exhibit a fair amount of integration of cognitive work in the absence of strong task interdependence. This means that the integration of cognitive work is not only a response to task interdependence.

7.5.2. Findings and reflections

In my study of researchers at the Group Buijs and OGIR I found both highly dependent research tasks and quite independent research tasks. Among highly interdependent (parts of) research tasks were shared problems. Most of the research is organized into, relatively small, projects. Project members working on the subtasks of such a project are confronted with team interdependence or reciprocal interdependence. Task interdependence exists also between researchers and their internal clients. The results of some of the research projects at both at the Group Buijs and OGIR were input for other research groups. Furthermore, researchers at OGIR and the Group Buijs outsourced experiments to others within the larger laboratory. These are forms of sequential and reciprocal task interdependence. But many other research tasks are quite independent. This can be derived from the fact that both in the Group Buijs and OGIR, the average number of project members was less than two. Perrow (1984) claims that R&D is in general characterized by a low degree of mutual dependence. This seems to be especially the case in the research projects in which the studied researchers were engaged. Product and process development projects involve much stronger interdependencies.

About half of the interactions that were characterized by integrated cognitive work, 33 out of 64, were related to interdependent tasks (cell (4)). Many of those interactions were conversations of project members about a shared problem. In these interactions participants suggest technical solutions, suggest experiments, describe findings and theory, describe own results, describe technologies, hypothesize, argue and ask questions. In these interactions researchers construct and deconstruct knowledge claims. The interactive constructing of answers is even more visible when researchers observe together and describe their observation, or calculate or try something on the spot. Take for example E56, an interaction between Jason and Rick. Three days earlier, Jason and Rick have thought up a series of spin-coating experiments that they would like to carry out in a clean room. In episode E56 they are executing these experiments, together with two technicians. They inspect coated discs by the bare eye and under a microscope. They tell each other what they see and draw conclusions. They perform scratch tests and look at the resulting scratches under a very strong microscope, again telling what they observe. They apply their knowledge and develop new insights with regard to shared problems. Within projects, research engineers are often responsible for the execution of experiments. Integrated cognition within a project can also consist of the development of instructions for a research engineer. Interactions characterized by integrated cognitive work in the face of task interdependence can also occur with non-project members. Researchers discuss their progress with other researchers who are dependent upon their results but are not a member of the same project. For example, in E237 Geoffrey discusses preliminary simulation results concerning the shape of a new catalyst particle with Michael, who is responsible for the design of the associated reactor. The design of the process depends upon the ultimate shape of the catalyst particle. Therefore he evaluates the preliminary findings of Geoffrey. Another topic of integrated cognition between non-project members is the prioritizing of problems to work on. In E238 Geoffrey has a discussion with other project members and their internal clients about the sequence in which a range of problems relating to the material that is to be used for the same catalyst particle, need to be attacked. Integrated cognition with regard to interdependent issues is also visible in a collective ambition workshop at OGIR (E272) in which the whole group discusses possible new directions of research. The above examples of integrated cognition are more or less required by the interdependence tasks. Such an integration of cognition in the face of a high degree of task interdependence was also found in earlier studies of distributed cognition.

However, many instances of technical communication were found that show a relatively high degree of integration of cognitive work with regard to tasks that are quite independent (cell (2)). Out of 64 interactions showing integrated cognition, 31 were not related to interdependent tasks. In these cases the presence of integrated cognition cannot be explained by task interdependence. An example is E37, described earlier, in which Jason thinks along with Marc. Many of those instances of 'thinking along' have been found. Integrated cognition without task interdependence was also found in group meetings. In E209, two researchers present a new research idea to 15 other group members at a lunch meeting. They describe a basic reaction, known to many chemical researchers, which has not been industrialized yet since it proceeds very slowly. The presenters explicitly ask their colleagues for ideas about how to speed up the process and to overcome some other difficulties. Their colleagues indeed come up with two possible solutions that raise the enthusiasm of the presenters. In interactions like these researchers come up with suggestions for technical solutions and experiments, hypotheses, evaluations, arguments, questions, doubts, conclusions and summaries with regard to somebody else's problem. Thinking along with someone involves applying one's knowledge to somebody else's problem and constructing and deconstructing bits and pieces that may eventually become part of a complete answer to a research question. As described in section 7.2, the transfer of existing information might also involve cognitive work oriented toward somebody else's problem. In pushing the sender considers something (potentially) useful for the receiver's work. This may involve findings or theory, information about technologies, experiments, and other researchers and information about other researchers and literature. In pushing, in contrast with pulling, an important share of the cognitive work associated with transferring is executed by the sender.

The literature on distributed cognition has showed the presence of integrated cognition in work situations that are characterized by a high degree of task interdependence. In the industrial research groups studied there is also integrated cognitive work when this is not requested by the interdependence of tasks. Also when tasks are independent, knowledge can be integrated by temporarily applying knowledge to somebody else's work. Also when tasks are independent, researchers can come up with ideas for each other's work. Also when tasks are independent, researchers can evaluate each other's work. In short, integrated cognition is also valuable when tasks are not interdependent.

In the first chapter of this thesis I raised the question whether the integration of knowledge is different from the integration of tasks. The finding that the presence of integrated cognition seems to be relatively independent from the degree of task interdependence suggests a positive answer to this question. The differentiation and integration of knowledge and cognition are partly independent from the differentiation and integration of tasks. Grant's (1996b) claim that the integration of knowledge is the primary problem that organizations face, might be a bit too strong. I do not believe that everything that can be said about the coordination of tasks can be re-interpreted in terms of the integration of knowledge. But the finding that the degree of integration of cognition is relatively independent from task interdependence, supports the idea that knowledge- and cognition-oriented theorizing about organizations adds value to task-oriented theorizing. A focus on the differentiation and integration of knowledge and cognition is a substantial addition to a focus on the differentiation and integration of tasks, and just a semantical shift

8.

CONCLUSIONS AND DISCUSSION

Previous research has determined that technical communication contributes to the performance of industrial research. However, I concluded in chapter one that little was known about the details of this contribution and the way it is realized. This study provided such insight. The concepts and taxonomies of moves, effects and origination mechanisms and the analysis of the role of knowledge and cognition enabled a detailed description and explanation of the variety of contributions of communication to industrial research practices. The first section of this chapter synthesizes the story. This leads also to a new explanation for the particular value of personal communication (section 1.3.4 described a number of existing explanations). Furthermore, I will reflect upon the use of the concept of knowledge sharing again and conclude that technical communication is a heterogeneous, active and integral part of research practices.

In chapter one I also stated the problem that the explanations of the IPA and the KBT of the value of technical communication were not based on in-depth, qualitative studies of this process. This has indeed posed to be a problem. Several assumptions of the IPA and the KBT were refuted on the basis of empirical findings of the present study. Other aspects, especially of the KBT, were supported and refined. The conclusions regarding the IPA and the KBT will be summarized in section 8.2.

In section 8.3. I will reflect upon the research approach taken in this study.

In the last section I will suggest directions for future research. Especially origination mechanisms and the differentiation and integration of knowledge and cognition are mentioned as issues worthy of further investigation. This thesis does not end with management implications, but I belief that it offers conceptual means to reflect on knowledge management instruments and problems.

8.1. A theory on the contribution of technical communication to industrial research practices

Many studies have found that communication contributes to the performance of industrial researchers. However, relatively little was known about the details of this contribution. The empirical goal of this study was to develop grounded theory, able to describe and explain the way technical communication contributes to industrial research practices and the way this is accomplished. The newly developed concepts and taxonomies of moves, effects, origination mechanisms yield the basis for a rich description and explanation of that contribution. They enable a conceptualization of the heterogeneity of technical communication in industrial research. They show technical communication to be an active accomplishment that is an integral part of industrial research practices.

THE CONTRIBUTION OF TECHNICAL COMMUNICATION

The contribution of communication is materialized in the effects it has. The taxonomy of effects I presented in chapter four shows the heterogeneous ways in which technical communication contributes to a researcher's work. In that chapter I made a distinction between direct contributions, i.e., effects that are part the process of constructing and solving problems, and indirect contributions, i.e., effects that are indirectly useful. Direct contributions include a change in the problem-portfolio one is working on, a contribution to a solution for a problem or actions that are undertaken as a result of communication (for example, being inspired to reflect upon a question). Indirect contributions consist of an increase of background knowledge or an increase of knowledge about the problems, activities and knowledge of others. These indirect contributions have a potential value for later research and communication. In chapter five I argued that the effect of communication is not always an increase of knowledge or a reduction of uncertainty or ambiguity. It may also create problems and questions, increase uncertainty and ambiguity. Further, communication may indeed yield answers, but may it also yield insights were no question existed. In short, communication plays a more active role than (only) filling pre-specified holes of uncertainty with information or knowledge.

Like effects show an active role for communication, the content of technical communication has an active nature as well. The active character of the content of technical communication was revealed by focusing on moves. This concept was partly derived from speech act theory. Moves are like acts. Linear communication models, which underlie much of the information processing and knowledge transfer literatures, envision the act of communication as an act of transferring. This has led to logistic interpretations of information processes (e.g., Huber 1982). Logistic analogies seem to be relevant for the technical side of communication. Think for example of talk about the electronic highway, the routing of information and the capacity of communication channels. However, if we look at the content of information, only some of the moves identified in chapter five resemble the transfer of a package to some degree. Take for example passing over a reference to an article or telling the characteristics of a material. Such acts might justify the logistic analogy. But researchers do more than describing states of affairs, more than telling facts to each other. Other moves are more like different acts. Researchers agree with someone else or reject what he says. They give arguments for a particular hypothesis. They suggest possible solutions. They suggest ideas for new research. They ask questions, sometimes critical questions. They make calculations on the spot. They instruct colleagues. In general, their moves consist of different types of descriptions, proposals, questions, evaluations and action-like moves. These moves may include an appeal, an urge. For example, advising someone to use a particular technology, is more than a description of that option. It includes an appeal to use it. These moves show technical communication to be an integral part of the work of researchers.

Many of these moves do not consist of the transfer of a finished piece of knowledge or information, but are contributions to a process of constructing knowledge. For that reason, and because of the conclusion that the effects of communication do not only consist in changes in knowledge, a distinction was made between knowledge transfer and knowledge-conducive communication in chapter five. This means that two main differences concerning the contribution of technical communication to industrial research practices were identified: a distinction between direct and indirect contributions and a distinction between knowledge transfer and knowledge-conducive communication. These distictions refer to different roles technical communication plays.

EXPLAINING DIRECT CONTRIBUTIONS

The differences between direct and indirect contributions and between knowledge transfer and knowledge-conducive communication can be partially explained by focusing on the way communication is realized. First, the story of the realization of direct contributions will be synthesized. One of the puzzles stated in the first chapter was this. On the one hand it is not obvious that communication is useful. Many things that can be said are irrelevant to others. On the other hand, apparently researchers realize useful communication, since it contributes to their performance. For themselves this might be self-evident. As social scientists however, we may step back and wonder how they accomplish this.

Origination mechanisms, a concept developed in this study, sketch the diverse ways in which technical communication can be realized. Chapter six showed that direct contributions are realized in three major ways: (1) via origination mechanisms oriented at a problem of alter or a shared problem; (2) without an orientation at a problem of alter or a shared problem; (3) by ego developing ideas oriented at his own problem. The first way accounts for most of the direct contributions (see Table 6.2). This seems intuitively plausible. Focused communication is more likely to be useful than unfocused communication. But one of the contributions of the concept of origination mechanisms is that it enables to show the different ways in which such an orientation can be realized and the associated preconditions.

Several origination mechanisms that are oriented at a problem of alter or a shared problem were found. Among these are the mechanisms labeled thinking along, collaborative problem solving, pushing and pulled originations oriented toward a problem of alter or a shared problem. These origination mechanisms cannot be used unrestrictedly. The effectiveness of these mechanisms depends upon the availability of knowledge and the knowledge processes involved (see section 7.2). In pulled originations, alter brings about such an orientation by asking focused questions to ego. The effectiveness of that mechanism is conditional upon alter's knowledge of his own needs and the knowledge of others. However, alter will not always know what knowledge of others might be useful for him. This means that communication practices that are solely based on information seeking are not as effective as they might be. Pushing, the selection of content by ego oriented at a problem of alter is often effective as well. This effectiveness is conditional upon ego's knowledge about problems of alter and his own background knowledge. Ego may provide information that alter has not thought of. However, in order to select information, that information should be available. But especially in research, many questions have not been answered yet. For example, in a certain episode John shows a disc that has broken in an experiment to Peter, an expert in fracture mechanics. Peter investigates the disc and draws a conclusion on the causation of the fractures. That conclusion did not exist before that interaction. Therefore, the development of new content oriented at a problem of alter or a shared problem can be a particularly valuable origination mechanism as well. The effectiveness of thinking along (development oriented at a problem of alter) and collaborative problem solving (development oriented at a shared problem) are conditional upon knowledge of the problem involved, background knowledge and the feasibility of developing relevant new content. Since each of these mechanisms oriented at a problem of alter or a shared problem have specific conditions, it is wise not to bet on only one mechanism.

The origination mechanisms characterized by a determination by ego, oriented at a problem of alter or a shared problem are not only effective, but also efficient. This can be explained by focusing on the knowledge integration taking place in those origination mechanisms. As Grant (1996b; 1997; 2001) emphasizes, knowledge transfer is not a particularly efficient mechanism for knowledge integration. It would be more efficient if each organization member executes those tasks for which he has the required knowledge. This is partly realized in those originations in which ego selects or develops with regard to a problem of alter or a shared problem. Some knowledge is integrated, i.e., is made productive in a coordinated way, without being transferred. In cases like the interaction between Jason and Luke about the optical filter, knowledge is applied that is not transferred (see section 7.3). The temporary application of Jason's knowledge to Luke's problem avoids that Luke has to acquire all relevant knowledge about optics. These forms of communication in fact economize on the amount of communication necessary. This advantage of developments or selections by ego with an orientation at a problem of alter cannot be understood when technical communication is only interpreted as information transfer or knowledge transfer.

The contribution of technical communication to industrial research practices can be explained further by relating the discussion of cognitive work in technical communication to the concept of distributed cognition. In those origination mechanisms in which ego selects or develops with an orientation at a problem of alter or a shared problem (thinking along, collaborative problem solving, pushing and the selection of content oriented at a shared problem), ego performs part of the cognitive work with regard to a problem of alter or a shared problem. In these episodes a certain distribution of cognition is realized. The social process of constructing and solving problems, of developing knowledge, gets organized in a particular way. In these origination mechanisms there is some degree of integration of cognitive work, i.e., the cognitive work performed by those involved overlaps to some extent. In this vein it resembles other distributed cognitive systems described in the literature. Industrial research may be a less integrated cognitive system than cockpit crews and other systems studied by distributed cognition theorists, but it is more integrated than is supposed by the concepts of information transfer and knowledge transfer. The distribution of cognition realized in thinking along, collaborative problem solving, pushing and the selection of content oriented at a shared problem has at least the following advantages. First, it may increase the variety of possible solutions generated, since the creativity of more persons can be employed. Second, it may increase reliability, since the evaluative capabilities of more persons are employed. Others may notice shortcomings that a researcher himself has overlooked. I hypothesize that these effects are reached in a time-efficient way. Others may come up with ideas or criticisms relatively quick – if they do not, not much time is spilled. These advantages of integrated cognition are not only relevant in the face of task interdependence. The effectiveness of the distribution and integration of cognition is partly independent from the distribution and integration of tasks.

Up to this point I have concentrated on the first of the three ways in which direct contributions are realized. Direct contributions can also be realized without an orientation toward a problem of alter and a shared problem, via 'diffusing' for example. One may pick up useful ideas from a presentation that is not oriented at one's own problem. Scientific journals, handbooks and databases are also cases of diffusing. If the focus of this study would have been more on those forms of communication, this way of yielding direct contributions would have presented itself as more important (see also Appendix 2). The effectiveness of diffusing depends upon the options available to the hearer or reader to select information from what is presented or to reinterpret what is said. Chance plays a role as well. However, the strength of personal communication does not lie in the realization of direct contributions in this way. Ego's knowledge is used only in a limited way in these forms of communication.

The third way to yield direct contributions that was mentioned in the beginning of this chapter is by self-suggesting. Self-suggesting shows the interwovenness of knowledge processes in technical communication, and therewith the active nature of technical communication. Among the 227 originations analyzed, 12 consisted of the development of new content with regard to one's own problem. In the beginning of chapter six I described E37, in which Marc talks about his problem to someone else. While describing his problem, he suddenly sees a new explanation for it. Cases like this call to mind a qoute from Weick: "*How can I know what I think until I see what I say?*" It illustrates that it is often impossible to separate different knowledge processes.

THE VALUE OF INDIRECT CONTRIBUTIONS

Direct contributions are not the only valuable effects of communication. Indirect contributions are indispensable. First, one never knows what knowledge one might need in the future. Knowledge that is not useful now may turn out to be so in the future (Garud and Nayyar 1994). Second, it is even seldomly clear what knowledge is useful at the present moment. Researchers are faced with 'radical uncertainty' (Tsoukas 1996). They do not know what knowledge may be of use, what 'recombinations' of knowledge are possible (Galunic and Rodan 1998). This calls for 'risky' communication – communication that is not certain to yield directly useful effects. When researchers only strive after directly useful communication, they will probably miss more unexpected contributions. Compare this with innovations: when all innovations of a company are successful, this probably means that they are not innovative enough. Radical innovation requires the taking of risks. Third, indirect contributions enable communication that yields direct contributions. The functioning of industrial research as a distributed cognitive system is not given once and for all. It should be enabled over and over again. Knowledge about others is of central importance for the functioning of a research laboratory as a distributed cognitive system. Herein lies the value of communication that is not oriented at a particular problem or oriented at a problem of ego. Frequently, interactions are made up of two parts. In the first part, one person explains his problem (reaction-demanding). In the second part, another person applies his knowledge to that problem (e.g., thinking along). But these two types of origination mechanisms do not always occur together. On the one hand, researchers may tell about their work without expecting and receiving a reaction. On the other hand, researchers may push or think along based on what they know about others from past occasions. In such cases, researchers draw on past indirect contributions as well.

KNOWLEDGE TRANSFER AND KNOWLEDGE-CONDUCIVE COMMUNICATION

The second major distinction regarding the contribution of communication is between knowledge transfer and knowledge-conducive communication. Knowledge-conducive communication consists of those moves in which no knowledge is transferred (such as questioning and hypothesizing) and effects that do not consists in an increase in knowledge (such as activating and changing problem-portfolio). A close look at Appendices 6 and 7 shows that those origination mechanisms in which new content is developed are associated most often with knowledge-conducive communication (though not necessarily so). It is often not new knowledge that is developed, but building blocks: suggestions, arguments, evaluations and questions. On the other hand, moves associated with the selection of content are the description of activities, findings, theories and technologies, referrals to literature and other persons, etc. These are more often expressions of justified and adequate beliefs (though not necessarily so). Origination mechanisms in which content is selected are therefore more likely to be part of knowledge transfer.

EXPLAINING THE PARTICULAR VALUE OF PERSONAL COMMUNICATION

Above I argued that the cognitive work associated with origination mechanisms oriented at a problem of alter or a shared problem explain the effectiveness and efficiency of the contribution of technical communication to industrial research practices. This effectiveness and efficiency manifests itself among others in an increase in creativity and reliability. This view of the cognitive work taking place in technical communication yields another explanation of the particular value of personal communication. In section 1.3.4 I mentioned a number of explanations that have been given in the literature: (1) interpersonal sources are more accessible and easy to use; (2) interpersonal sources contain information that cannot be found in published sources; (3) interpersonal communication provides emotional support as well; (4) interpersonal communication is a richer medium, i.e., it is more able to deal with ambiguities, by offering the opportunity for multiple cues and checks of understanding; (5) interpersonal communication is more suited for the transfer of tacit knowledge (in a process of socialization). This last explanation is favored in the recent literature on knowledge in organizations (e.g., Nonaka 1994; Hansen 1999). Based on chapters six and seven I would like to propose another explanation. Personal communication, as opposed to reports and databases for example, enables origination mechanisms that are oriented at a problem of alter or a shared problem. The application of knowledge within these origination mechanisms makes them effective and efficient. It is the cognitive work found in many instances of interpersonal technical communication that makes it the more valuable. This is far more difficult in communication via published sources (these constitute predominantly instances of 'diffusing'). This explanation is partly at odds with the explanation in terms of the transfer of tacit knowledge. The application of knowledge in interactions may avoid the transfer of tacit knowledge. Nevertheless, I do not claim that this is the only explanation. The different explanations are not contradictory. The other factors may play a role as well.

KNOWLEDGE SHARING

This study started as a study of knowledge sharing. However, due to the conceptual obscurity of this concept, the main body of this thesis has spoken of technical communication. Now it is time to reflect upon the concept of knowledge sharing again. As explained in chapter one, this concept sounds more sympathetic and less rigid than knowledge transfer. Nevertheless, these concepts are often used interchangeably. The detailed analyses of technical communication presented in this thesis allow us to draw sharper boundaries around the concept. Several alternative ways to attach a more delineated meaning to the concept of knowledge sharing are conceivable. One way is to identify sharing and transferring. That would imply that only a part of technical communication can be interpreted as knowledge sharing, since not all technical communication consists of knowledge transfer and more knowledge processes are involved than only transferring. Another option is to draw its conceptual boundaries broadly, in order to encompass all technical communication processes. However, that would leave its meaning under-specified. The extension of the concept would be clear, but it would remain unclear what it is about technical communication that makes it knowledge sharing. A third option would be to interpret sharing as the use of a common good. Like sharing a room implies using a room together, we could interpret knowledge sharing as the application of knowledge for the benefit of oneself or another person in interaction. In that case, both the transfer and application of knowledge in communication would count as knowledge sharing. This implies, for example, that the knowledge that is not transferred but only used in interaction, is knowledge that is being shared as well. That does not necessarily imply that all technical communication is an instance of knowledge sharing in this interpretation, but it surely broadens the range of processes captured by the concept of knowledge sharing. Moreover, it would be in accordance with the communal connotations of the concept. I do not intend to fix a meaning for the concept of knowledge sharing once and for all. But, since different types of technical communication are not interchangeable, it is necessary to make it clear what instances of technical communication are referred to when one claims to study knowledge sharing.

8.2. Information processing approach and knowledge-based theory

In chapters five and seven I reflected upon the research results from a conceptual and theoretical perspective. In chapter one I explained that this thesis is rooted in the knowledge-based theory of the firm and the information processing approach. In the field of organization and management studies have most to say about technical communication in industrial research. Vice versa, technical communication is most relevant to these fields of research. Though knowledge oriented perspectives are more popular these days, the contribution of the information processing approach should not be forgotten. Ideally, we should learn how these perspectives are related and in which ways the knowledge-based theory adds to the earlier information processing view. In this section I will pull together the threads with regard to these theories. I will not attempt to unify them. I do not know whether that is possible. But I will discuss how the knowledge-based theory adds insight to the information processing approach and how the present study adds insight to both of them.

INFORMATION PROCESSING APPROACH

The basic line of reasoning of the information processing approach with regard to technical communication is the following (see Galbraith 1973; 1977; Tushman and Nadler 1978; Daft and Lengel 1986). Technical communication, when valuable, consists of information transfer. The value of information transfer is that it reduces uncertainty or ambiguity, posed by task characteristics, task interdependencies and the environment. Reduced uncertainty and ambiguity are associated with higher performance. On the other hand, technical communication costs time, money and attention. This means that it has a negative impact on performance as well. Organizations that match the amount, direction and richness of technical communication to the existing uncertainty and ambiguity perform better. In chapter one, these relationships were represented in a figure adapted from Tushman (1978) and Daft and Lengel (1986). Figure 8.1 gives another schematic representation of these relations.

The empirical findings and theoretical reflections in this thesis add to the existing information processing theory, but question some of its assumptions as well. The concept of origination is an addition – therefore I added it to Figure 8.1. The IPA has not paid attention to the way technical communication is initiated. Nevertheless, I have shown that the origination of technical communication is not a trivial matter and influences the effects of communication. Furthermore, some origination mechanisms are associated with more information processing than just transferring information.

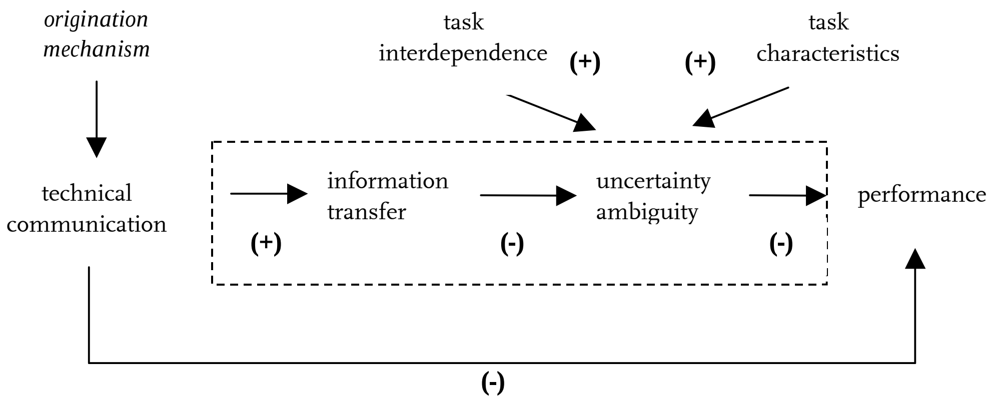

Figure 8.1. Outline of information processing model

The empirical findings concerning moves and effects pose problems for the line of reasoning of the information processing approach. I argued in chapter five that the heart of the explanation linking technical communication, contingency factors and performance does not hold. Therefore I have drawn a dotted line around this part of the explanation. Not all relevant effects can be qualified as uncertainty or ambiguity reduction. Technical communication may increase uncertainty and ambiguity. Uncertainty is not always a bad thing and the existence of conflicting opinions neither. In research it is often better to face the increased uncertainty of considering more options and looking for more evidence than limiting uncertainty by focusing on a limited number of options.

Further, I argued in chapter five that the concept of information is not as self-evident as it is often treated. Several interpretations of information are irrelevant for the explanation of the IPA. Other interpretations are too restricted to substantiate the claim that useful communication consists of information transfer. The one interpretation of the concept of information that supports the explanation of the IPA is not very illuminating. It just says that a message is informative when it is in some way useful. But that interpretation implies that the strong link between information and uncertainty, which is dear to Galbraith (1973; 1977), is cut through. Likewise, the demand that data should be able to yield knowledge in order to qualify as information, which is posed by Tushman and Nadler (1978), should be dropped. Since, in this weak interpretation, information may be valuable in others ways than reducing uncertainty or increasing knowledge. These conclusions imply that the original reasoning of Galbraith (1973) and Tushman and Nadler (1978) and the extension proposed by Daft and Lengel (1986) do not inadequately explain the value of all technical communication. The theoretical elegance of the information processing approach is harmed.

The fact that the explanation of the IPA is insufficient, means that its way of explaining the 'fit' between technical communication on the one hand and task characteristics and task interdependence on the other hand is not satisfactory. This implies, among other things, that given certain task characteristics and task interdependencies, it is not possible to determine the need for technical communication. Perhaps this deficiency might be resolved by improved conceptualizations of information, uncertainty and ambiguity. But the deficiency of the explanation of fit may also be the result of more fundamental problems. For example, the IPA assumes that an organization needs to fit its technology. Technology is seen as a source of task characteristics and interdependence (e.g., Thompson 1967). However, recent work on the relationship between organization and technology has stressed the interactive nature of this relationship (e.g., Orlikowski 1992). The idea of fitting the organization to its technology might be too static. The same holds for the idea of fitting information processing needs to information processing capacity. Research tasks are created and recreated in research practice. Communication plays in role in that process as well. This might imply that there is no information processing need that can be determined in advance.

KNOWLEDGE-BASED THEORY OF THE FIRM

The KBT is the most integrated perspective on knowledge and knowledge processes in organizations. The KBT was introduced in the first chapter of this thesis. Its explanation of the value of technical communication runs as follows (see Figure 7.1). Technical communication is interpreted as knowledge transfer. Organizational performance depends on the integration of specialized knowledge. One way of integrating knowledge is by transferring it. This is useful when others have knowledge a researcher himself lacks. This explanation sounds familiar from the perspective of the technical communication studies by Allen, Tushman and others. Tushman (1978: 628) writes: *"Since project members often will not have all the appropriate information within their group, they must import information and ideas from outside the project"* . However, from the perspective of the KBT, this argument itself is not yet fully convincing. Grant (1996b) argues that knowledge transfer is not the most efficient mechanism for the integration of knowledge. It can be more efficient to adapt tasks to knowledge in stead of the reverse. *"If production requires the integration of many people's specialist knowledge, the key to efficiency is to achieve effective integration while minimizing knowledge transfer through cross-learning by organizational members. If Grant and Spender wish to write a joint paper together, efficiency is maximized not by Grant learning everything that Spender knows (and vice versa), but by establishing a mode of interaction such that Grant's knowledge of economics is integrated with Spender's knowledge of philosophy, psychology and technology, while minimizing the time spent transferring knowledge between them."* (Grant 1996b: 114).

At first sight, it may seem to pose a problem for the explanation of the KBT that not all technical communication consists of knowledge transfer and that other knowledge processes play a role as well. The explanation from technical communication to performance passes through knowledge transfer. However, at second sight, these findings support the KBT even more strongly. In chapter seven I showed that some of the processes of knowledge application and knowledge generation associated with different origination mechanisms can be reinterpreted as different knowledge integration mechanisms. In thinking along, for example, someone temporarily applies his knowledge to a problem of someone else. This knowledge integration mechanism is more efficient than knowledge transfer, since not all knowledge that is integrated needs to be transferred. This means that in Figure 7.1 an arrow should be added, running from 'technical communication' to 'other knowledge integration mechanisms'. Grant's elaboration of the KBT should not necessarily be tied to an interpretation of technical communication as knowledge transfer. The focus of the KBT on the knowledge that needs to be integrated, in stead of solely focusing on the transfer of knowledge or information, proves to be an advantage above the IPA. Thus, this is one way in which the KBT adds to the information processing approach. In chapter seven I concluded in general that the focus on the integration of knowledge and cognition is a substantial and valuable addition to a focus on the integration of tasks alone. However, I explained in chapter seven that knowledge integration by temporarily applying one's knowledge to another one's problem in interaction does not fit in Grant's classification of mechanisms. Therefore, the description of knowledge integration taking place in technical communication contributes to the nascent KBT.

One more advantage of a knowledge-based perspective has to do with the concepts of knowledge versus uncertainty and ambiguity. We saw above that the information processing approach has difficulties with uncertainty and ambiguity. Not all useful communication can be identified as uncertainty or ambiguity reduction. In the information processing model, uncertainty and ambiguity derive from task characteristics and interdependencies. However, it may be argued that communication is not only meant to react passively upon the needs stemming from given task characteristics, given interdependencies and a given environment. In interaction, researchers also create their research problems. Communication has an active role. Though this is difficult to accommodate with the concepts uncertainty and ambiguity, it is easier to do with the concept of knowledge. Reducing uncertainty and ambiguity is like filling an existing hole. Creating knowledge is like building a new house. Knowledge creation is a more active model than information processing (Nonaka 1994). Moreover, the different moves can be understood from the perspective of knowledge creation.

However, this poses difficulties for the KBT as well. Grant is focused on the efficiency of knowledge integration. This presupposes that there is a required level of knowledge integration that should be realized in the most efficient way. However, the KBT does not offer a criterion to determine the required level of knowledge integration, like the IPA yields a criterion for the required level of information processing. But like the criterion for the IPA is not perfect it is unlikely that it is possible to develop a clear criterion for the required level of knowledge integration. Especially in exploration, people in organizations are faced with 'radical uncertainty', i.e., they do not know what they need to know (Tsoukas 1996). Some recombinations of knowledge might yield new capabilities, but others do not. That is hard to determine in advance. Transferring knowledge might not be efficient when considering the execution of current tasks, but might yield unexpected new recombinations of knowledge.

8.3. Reflection on research approach

Much of the seminal literature on knowledge in organizations was conceptual in nature. Think for example of the work by Nonaka (1994), Blackler (1995), Spender (1996), Tsoukas (1996) and Grant (1996b). Over the last couple of years more empirical studies have appeared. The present study fits in that trend. Generally speaking, this study was characterized by a qualitative, exploratory yet structured approach. Such an approach has the advantage that it enables the discovery of new phenomena and the exploration of concepts. I belief that this study succeeded in doing so. However, an exploratory, grounded theory approach has some potential drawbacks as well. The grounded theory approach does not start with much theory. This has as a potential drawback that it might lead to research results that are detached from current theorizing. In this thesis I have tried to avoid this problem by elaborate reflections upon existing theories and existing literature. I have tried, where possible, to indicate which findings are in line with existing literature, which findings add to existing literature and which findings contradict existing literature. But due to the fact that I have not positioned this research within a single theoretical background, I have been forced to keep an eye on several streams of literature inside and outside the field of organization science. Grounded theory research should be complemented with other approaches that emphasize theory testing and theory integration.

The way in which I described technical communication has enabled me to analyze a number of aspects in depth. I focused on the analytical distinction of aspects and parts of interactions. Technical communication was cut in pieces, in distinct effects, moves and the way these moves are realized. A drawback of this analytical approach is that the ongoing story of interactions, their ongoing 'flow', has gotten somewhat out of sight. I have tried to remedy this by providing the stories about single interactions. But I have not investigated the sequence of moves within one interaction, let alone sequences of interactions. This study has not resulted in a full anthropological description of the research groups either. Communication episodes were the unit of analysis, and not the research groups. Therefore, I do not claim that the concepts employed in this thesis exhaust all that can be said about the process and content of technical communication. During the analyses, delimiting choices have been made. Other findings may complement the ones presented here. This holds for example for the social aspects of technical communication. Communication is an active cognitive and social accomplishment, but I have only concentrated on the cognitive side of this accomplishment in this thesis.

Another issue I would like to say something about is the study of knowledge. The concept of knowledge is easy to discuss theoretically, but quite difficult to study empirically. In contrast with a large share of the literature on knowledge processes in organizations, I studied knowledge processes by direct observation. This has proved to be possible, but difficult. The real life study of knowledge processes is complicated when the object of the study involves the expert knowledge of professionals. Lacking this knowledge made it much more difficult to understand what was happening within interactions. Further, the philosophical analysis of knowledge is based on quality criteria that beliefs should meet. Epistemologists speak of knowledge when beliefs are justified and true. They even make complicated calculations on truth-values

(Goldman 1999; Berends 2002). But in a frontline research environment it is difficult for insiders to evaluate beliefs on these criteria. Researchers earn a living by evaluating knowledge claims. The application of these criteria is even more difficult for an outsider. This leads to the fact that the criterion considered to be most relevant to epistemologists, truth, does not appear in my empirical findings. Such criteria are easy to discuss but hard to apply. Notwithstanding these difficulties, I believe that this study has yielded valuable findings about knowledge processes (but is that belief justified and true?).

Finally, it might be argued that I have sketched a rather positive image of technical communication. I have studied interactions and not the absence of interactions. I have not studied cases in which things went wrong, or could have gone better, due to an absence of communication. Further, I have studied the research-related effects of communication and not the costs of communication. To a certain extent I consider the positive image of communication that I sketched warranted. Both the researchers at OGIR and the Group Buijs were very satisfied with the technical communication processes within their groups and with the rest of the laboratory (their dissatisfaction concerned managerial issues, as is quite normal for professionals). For example, the young researcher Rick talked about the network he was building in the laboratory: *"It is nice. Once you start up building that ... the amount of knowledge that you can get!"* (NL 990622). Nevertheless, a full anthropological description of the communication practices within a research group should deal with uncomfortable issues as well.

8.4. Suggestions for future research

The present study and its results suggest several directions for future research. An obligatory remark at this point is that this exploratory research calls for more rigorous and more extensive testing. Since the chance that mere replications of research like this are performed is close to zero, it makes more sense to suggest ways to elaborate upon findings from this research.

I think that the concept of origination mechanisms is worthy of further elaboration. The following questions seem interesting to me. First, are the same origination mechanisms employed in different situations? Are the same dimensions of origination relevant in development, engineering, production and other organizational functions? Can interactions between organizations also be described in terms of these mechanisms? Second, what other situational characteristics, besides knowledge and knowledge processes, influence the effectiveness of particular mechanisms? Third, what factors influence the use of origination mechanisms? These may include personal, organizational and technological factors. Concerning this last type of factor, an interesting question would be to what degree new media and ICT tools enable each of the different origination mechanisms. In this study I have focused predominantly on face-to-face communication. Are the same origination mechanisms possible in computer mediated communication? Fourth, it would be theoretically interesting to know how origination mechanisms (and moves and effects) relate to other theoretical concepts. Are, for example, particular genre's (Orlikowski and Yates 1994; Yates et al. 1999) associated with particular origination mechanisms? Are particular 'Knowledge Management Practices' (Coombs and Hull 1998; Hull et al. 2000) associated with particular origination mechanisms?

A study of each of these issues gains in value when origination mechanisms are measured rigorously. In future research it would be advisable to devise ordinal or higher order scales for the dimensions of origination. In this research I coded parts of interactions at nominal scales. An origination was either coded as existing or new, either coded as determined by ego, by alter or by management, either coded as oriented at a problem of ego, at a problem of alter, at a shared problem or at no particular problem at all. But it is often a matter of degree in which the originations of a person in an interaction are determined by ego, alter or management and a matter of degree in which an origination is oriented at a problem of ego, alter, a shared problem or no problem at all. Therefore it may be a better option to devise more continuous scales. The same holds for moves and effects. In this research I have coded nominally: a certain type of move or effect is present in an interaction or not. However, it would be more informative to gain insight in the degree to which moves or effects are present. For example, in that way Okada and Simon (1997) found that especially the amount of requests for explanation determines the performance of collaborative problem solving.

In this thesis the discovery of origination mechanisms has led to reflections on the cognitive processes that constitute technical communication. I concluded that different knowledge processes are at work in technical communication. Further, I concluded that a certain distribution of cognitive work is realized in technical communication. These issues deserve further investigation. First, the classification of knowledge integration mechanisms, initiated by Grant (1996b) should be improved. It is unclear on which grounds Grant distinguishes knowledge integration mechanisms. Moreover, the knowledge integration mechanism involved in 'thinking along', temporarily applying one's knowledge to another one's problem, does not fit in Grant's scheme. Second, the distribution of cognitive work in research deserves further study. The KBT and the literature on distributed cognition claim that particularly the way in which knowledge and cognition are differentiated and integrated determine group and firm performance. The current project has yielded some insight into the role of technical communication with regard to these issues. Further questions concern for example the distribution of cognition over the course of research projects, its influence on knowledge creation and its relation to the formal division of labor.

The taxonomies of moves, effects and origination mechanisms can also be used to reflect on knowledge management problems and instruments. I will not give any immediate knowledge management guidelines at this place. There are several reasons to refrain from doing so. First, I have argued in chapter two that this study was not oriented at external validity. Prescriptive claims presuppose generalizability. Second, in the field of organization science, descriptive and explanatory theories are not directly translatable into prescriptions. An adequate theory does not automatically yield adequate management implications. Management problems are situated. Not all factors that play a role in a specific situation will be incorporated in a theory. General guidelines that follow from a theory need to be combined and adapted to specific situations. Furthermore, these specific guidelines should be tested first. We can translate this issue into the terms developed in this thesis. Giving management implications at this point would be a case of 'existing, determined by ego, not oriented at a particular problem'. In chapter six I showed that that origination mechanism is not very effective in yielding direct contributions. My research has been oriented at theoretical problems and not at a particular management problem. In order to yield useful management guidelines, other methodologies are required, methodologies that are oriented at particular management problems (e.g., van Aken 2001). Finally, I have not used a performance measure in this research. The closest I have come to a performance measure is the distinction I made between direct contributions and indirect contributions. By their nature, direct contributions are more directly valuable. But indirect contributions are valuable as well. I can offer no guideline to determine what degrees of direct and indirect contributions is optimal. Moreover, in my critiques of the IPA and the KBT I have argued that it is very difficult to determine what level of communication in general is optimal. Nevertheless, I believe that this research can be of value for organizational practice. The taxonomies of origination mechanisms, moves and effects and the relationships found between them may be used to reflect on particular knowledge management problems and instruments. One may ask which origination mechanisms are supported and how this influences moves and effects. This study does not directly yield solutions, but may provide the conceptual means to think about these problems.

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Appendices

Appendix 1: Main sources of information used in innovation projects

	internal	*external*	*personal*
Baker et al. (1967: 159)	66	6	27
Isenson (1969: 162)	39	61	-
Myers and Marquis (1969: 53)[44]	52	35	-
Rosenbloom and Wolek (1970: 35)	52	48	-
Utterback (1971: 130)	46	47	7
Langrish et al. (1972: 78, 79)	36	35	29
Johnston and Gibbons (1975: 29)	30	34	36
Goldhar et al. (1976: 55,56)	48	22	30
Faulkner and Senker (1995: 222)	51[45]	49	-

[44] The remaining 13 percent stemmed from multiple sources.
[45] This includes the use of personal sources.

Appendix 2: Main channels of information used in innovation projects

	personal	*literature*	*other*[46]
Herner (1954: 230)	40	60	
Myers and Marquis (1969: 53)	26	7	67
Rosenbloom and Wolek (1970: 35)	55	45	
Utterback (1971: 130)	38	13	49
Johnston and Gibbons (1975: 30)	37	29	34
Goldhar et al. (1976: 56)	71	29	
Gerstenfeld and Berger (1980: 170)	48	52	

[46] This refers to personal experience, experiments and multiple sources.

Appendix 3: Studies of technical communication and performance

author	*who*	*with whom*	*effect on performance*
Hagstrom (1965)	scientists scientists	intradepartmental extradepartmental	positive (?)[47] positive (?)
Pelz and Andrews (1966)	Ph.D.s in research, development and engineers Ph.D.s in research, development and engineers	direct colleagues extradepartmental	positive (s) positive (s)
Rothwell et al. (1974)	innovation projects innovation projects	internal external	positive (s) positive (s)
Allen (1977)	R&D projects R&D projects	intraproject extraproject	no effect positive (s)
Katz and Tushman (1979)	research projects research projects research projects research projects research projects development projects development projects development projects development projects development projects	project members division members laboratory members corporation external project members division members laboratory members corporation external	positive (s) negative (ns) negative (ns) negative (ns) positive (s) positive (ns) negative (ns) positive (ns) positive (s) mixed (ns)
Allen et al. (1979)	research projects development projects	external external	positive (s) negative (ns)
Tushman (1978)	research projects research projects research projects research projects	project members group members rest of organization external	positive (?) positive (?) negative (?) positive (?)
Allen et al. (1980)	research projects research projects research projects development projects development projects development projects	project members rest of laboratory rest of organization project members rest of laboratory rest of organization	positive (ns) negative (ns) negative (ns) positive (ns) positive (ns) positive (s)
Katz (1982)	R&D projects	total communication	positive (?)
Hauptman (1986)	software developers software developers software developers	project members within department rest of business	no effect positive (s) positive (ns)

[47] In this column, (s) stands for a significant result ($p<0.05$), (ns) for a not-significant result and (?) for a finding for which no significance level is given.

		division	
Ancona and Caldwell (1992a)	NPD projects	rest of organization	positive (s)
Keller (1994)	industrial R&D projects	total communication	positive (s)
Hoopes and Postrel (1999)	software development	within project	positive (s)[48]

48 More precisely, Hoopes and Postrel found that "glitches", problems due to a lack of knowledge sharing, have a significant negative effect.

Appendix 4: Antecedents of knowledge sharing and information transfer[49]

	Amount / frequency	*Quality / success / difficulty*
Knowledge characteristics		
tacitness ((-) codification, causal ambiguity, observability)[50]	(-) Galunic and Rodan (1998) (-) Schulz (2001)*	(-) Collins (1974)* (-) Winter (1987) (-) Zander and Kogut (1992, 1995)* (-) Szulanski (1996, 2000)* (-) Galunic and Rodan (1998) (-) Hansen (1999)* (-) Moenaert et al. (2000)*
(perceived) quality (provenness, trustworthiness, credibility)	(+) Leckie et al. (1996)ˆ (+) Ardichvili et al. (2002)*	(+) Leckie et al. (1996)ˆ (+) Moenaert and Souder (1996)* (+) Szulanski (1996, 2000)* (+) Ardichvili et al. (2002)*
(perceived) usefulness (value of knowledge stock, novelty, information richness, relevance, uniqueness)	(+) Gupta and Govindarajan (2000)* (+) Schulz (2001)* (+) McDermott and O'Dell (2001)	(+) Moenaert and Souder (1996)* (+) Ardichvili et al. (2002)*

49 Constructing such an overview necessitates making some simplifications. In this overview no distinction is made between knowledge transfer, knowledge sharing and information transfer. This seems to be justified since, first, these terms are often used interchangeably, and, second, successful information transfer consists in many interpretations of the concept of information in an increase of knowledge (Tushman and Nadler 1978; Dretske 1981). Furthermore, no distinction has been made between knowledge sharing between individuals and knowledge sharing between departments. Factors influencing knowledge transfer between organizations have been left out of consideration as have factors that influence the adoption of externally developed technological innovations (e.g., Glaser 1983; Rogers 1995). Finally, interaction effects and contingency factors have been omitted. In some cases these are mentioned in an explanatory footnote. In this table the following signs are used: (-) (first column) this concept is inversely synonymous to the others; (-) / (+) / (0) this author reported a negative effect / positive effect / no effect; a star (*) behind a reference means that the author(s) found empirical evidence for the factor; a ˆ sign behind a reference means that the author(s) refer to earlier studies to substantiate their claim.

50 Concepts between parentheses are synonyms or closely related concepts. To keep the size of the table limited, these may include not completely overlapping concepts.

relatedness (context dependency, embeddedness, interconnectness, complexity)		(-) Winter (1987) (-) Galunic and Rodan (1998) (-) Hansen (1999)* (-) Birkinshaw et al. (2002)*
comprehensibility (packaging, right quantity, well-organized)	(+) Leckie et al. (1996)^	(+) Moenaert and Souder (1996)*
timeliness	(+) Leckie et al. (1996)^	
source		
motivation general (individual commitment)	(+) van der Bij et al. (2003)*	(+) Szulanski (1996, 2000)*
extrinsic motivation (rewards)	(+) Huber (1991)^ (0) Constant et al. (1996)* (+) Weiss (1999) (0) Gupta and Govindarajan (2000)* (+) Osterloh and Frey (2000)[51] (0) van der Bij et al. (2003)*	(+) Huber (1991)^
intrinsic motivation (enjoying helping others & solving problems, contribution to self-esteem / prestige	(+) Constant et al. (1996)* (+) Weiss (1999) (+) Osterloh and Frey (2000)[52] (+) Ardichvili et al. (2002)*	
perception of relevance for receiver ((-) uncertainty about relevance)	(+) Huber (1991)^ (-) Ardichvili et al. (2002)*	
workload	(-) Huber (1991)^	(-) Huber (1991)^
knowledge is power attitude (secrecy)	(-) Davenport et al. (1992) (-) Andrews and Delahaye (2000)* (0) Ardichvili et al. (2002)*	
expected contribution to organization goals (moral obligation, community interest)	(+) Constant et al. (1996)* (+) Ardichvili et al. (2002)*	
amount of knowledge (expertise; internally	(+) Andrews and Delahaye (2000)*	(+) Constant et al. (1996)* (+) Szulanski (1996, 2000)*

[51] Osterloh and Freh (2000) argue that extrinsic motivation is particularly effective for sharing explicit knowledge, but not for tacit knowledge.
[52] Intrinsic motivation is considered to be required for the transfer of tacit knowledge.

developed or acquired; perceived reliability of source)	(+) Schulz (2001)* (+) Hansen (2002)*	(+) Hansen (2002)*
role (gatekeeper)	(+) Allen and Cohen (1969)*	
receiver		
Not-Invented-Here syndrom	(-) Katz and Allen (1982)*	(-) Szulanski (1996, 2000)*
absorptive capacity	(+) Cohen and Levinthal (1990)* (+) Lane and Lubatkin (1998)*	(+) Cohen and Levinthal (1990)* (+) Szulanski (1996, 2000)* (+) Lane and Lubatkin (1998)*
retentive capacity		(-) Szulanski (1996, 2000)*
gender: female	(0/+) Lee (1997)*	
pleasure of solving problem alone	(-) Lee (1997)ˆ	
awareness of information / knowledge (metaknowledge, who knows what, who does what)	(+) Pelz and Andrews (1966) (+) Wegner (1987) (+) Leckie et al. (1996)ˆ (+) Weiss (1999)	
relationship / channels		
power / status difference	(+) Collins (1974)*[53] (+) Huber (1991)ˆ[54] (-) Lee (1997)* (-) Weiss (1999)	
strength of link ((-) number of intermediate links, familiarity / prior success with source, prior communication)	(+) Huber (1991)ˆ (+) Leckie et al. (1996)ˆ (0) Constant et al. (1996)* (+) Dyer and Nobeoka (2000)*	(+) Huber (1991)ˆ (+) Szulanski (1996, 2000)* (0) Constant et al. (1996)* (+) Hansen (1999)*[55]
trust (psychological safety friendship, group cohesiveness; social confidence; social interaction)	(+) Blau (1963)* (+) Keller (1986)ˆ (+) Wathne et al. (1996)* (+) Edmondson (1999)* (+) Weggeman and Berends (1999)	

[53] Collins (1974) found that more powerful organizations were more willing to share knowledge.
[54] Huber (1991) reports that a person A is more willing to transfer information to a person B when B has more power or status.
[55] Hansen (1999) found this effect only for the transfer of non-codified and dependent knowledge. Weak ties are found to be more suitable for the transfer of codified and non-dependent knowledge.

	(+) Weiss (1999) (+) de Long and Fahey (2000) (+) Andrews and Delahaye (2000)* (+) Ardichvili et al. (2002)* (+) Tsai (2002)*	
similarities of work (member of same group, CoP, involvement in same practice, same function)	(+/-) Ancona and Caldwell (1992a)*[56] (0) Constant et al. (1996)* (+) Brown and Duguid (1998) (+) Hislop et al. (2000)*	(-/+) Constant et al. (1996)* (+) Brown and Duguid (1998) (+) Hislop et al. (2000)*
similarity of identity (demographic, shared sense of identity)	(+) Galunic and Rodan (1998) (+) Hislop et al. (2000)* (+) Dyer and Nobeoka (2000)*	(+) Galunic and Rodan (1998) (-) Constant et al. (1996)*
common stock of basic knowledge (shared coding scheme, overlap in basic knowledge; common jargon; (-) difference in thought worlds)	(+) Tushman (1978)* (+) Kogut and Zander (1992) (+) Grant (1996a)^ (+) Galunic and Rodan (1998) (+) Lane and Lubatkin (1998)* (+) Bosch-Sijtsema (2002)*	(+) Dougherty (1992)* (+) Galunic and Rodan (1998) (+) Lane and Lubatkin (1998)* (+) Bosch-Sijtsema (2002)*
differences in knowledge (specialized knowledge; (-) organizational redundancy)	(-) Stasser et al. (1995)* (-) Galunic and Rodan (1998) (0) Lane and Lubatkin (1998)* (+) Dyer and Nobeoka (2000)* (+) van der Bij et al. (2003)*	(-) Galunic and Rodan (1998) (0) Lane and Lubatkin (1998)*
reciprocity	(+) Blau (1963)* (+) Collins (1974)* (+) Faulkner and Senker (1995)* (+) Weiss (1999)	

[56] Ancona and Caldwell (1992a) found that the functional diversity within a project group stimulates communication with other organization members outside that project group. This is explained by the fact that group members with a particular functional background communicate easier with others with the same background.

	(+) Schulz (2001)*	
costs (time; (-)accessibility)	(-) Gerstberger and Allen (1968)* (-) Huber (1991)^ (-) Weiss (1999) (-) Ardichvili et al. (2002)*	(-) Gerstberger and Allen (1968)* (-) Leckie et al. (1996)^
richness of communication channel	(+) Gupta and Govindarajan (2000)* (+) Bosch-Sijtsema (2002)*	(+) Daft and Lengel (1984)
physical proximity ((-) geographical dispersedness, co-location)	(+) Allen (1977)* (0/+) Moenaert and Caeldries (1996)* (0) Darr and Kurtzberg (2000)* (+) Bosch-Sijtsema (2002)* (0) van der Bij et al. (2003)*	
organizational context		
congruence (strategic similarity, customer similarity, goal congruence, structural similarity)	(+/-) Lane and Lubatkin (1998)* (+/0) Darr and Kurtzberg (2000)* (+) Tsai (2002)*	(+) Lane and Lubatkin (1998)* (+) Moenaert et al. (2000)*
long term orientation	(+) van der Bij et al. (2003)*	
organizational crisis	(+) van der Bij et al. (2003)*	
formalization	(+) Menon and Varadarajan (1992) (-) Moenaert et al. (2000)^ (+) Moenaert et al. (2000)*	(+) Menon and Varadarajan (1992) (-) Moenaert et al. (2000)^ (+) Moenaert et al. (2000)*
centralization	(+) Menon and Varadarajan (1992) (-) Tsai (2002)*	(+) Menon and Varadarajan (1992)
'positive' organizational norms (collectivism; cross-functional and interunit climate; pro-innovation culture, pro-information culture; knowledge oriented culture)	(+) Menon and Varadarajan (1992) (0/+) Lee (1997)* (+) de Long and Fahey (2000) (+) McDermott and O'Dell (2001) (+) Ardichvili et al. (2002)*	(+) Menon and Varadarajan (1992) (+) Moenaert et al. (2000)*
transparency of communication network	(+) Moenaert et al. (2000)*	

communication infrastructure (information technologies)	(+) Moenaert et al. (2000)* (0) van der Bij et al. (2003)*	(+) Moenaert et al. (2000)*
formal integration mechanisms (liason personnel, task forces, permanent committees, management support for integration)	(+) Gupta and Govindarajan (2000)* (+) Moenaert et al. (2000)* (+) Dyer and Nobeoka (2000)* (+) Birkinshaw et al. (2002)* (0) van der Bij et al. (2003)*	(+) Gupta and Govindarajan (2000)* (+) Moenaert et al. (2000)*
group tenure	(+/-) Katz 1982*[57] (+) Bosch-Sijtsema (2002)*	

[57] Katz (1982) found a curvilinear relationship between group tenure and technical communication, with an optimum around a mean tenure of 3 to 4 years.

Appendix 5: Quantitative analyses

For the quantitative analyses I have tried to code a total of 146 interactions. A subset of 33 of them was not codeable at all, because they were either too meagerly described in my observations or were not really research related. Examples of these were lunches in which no research-related topics were discussed. Many of the remaining interactions have been divided into parts, so that every part could be coded exclusively as one type of origination. These parts were coded for origination mechanism, moves and effects. Episodes that could not be coded on each of the codes due to a lack of information were removed from the data. Finally a subset of 227 episodes remained, stemming from 102 instances of technical communication. These episodes comprise accidental meetings at the corridor, lunches and coffee-breaks, interactions between persons occupying the same room, organized meetings, reports, purposeful visits, telephone calls and some e-mails. From these 227 episodes, 129 stem from the Group Buijs and 98 from OGIR. All of the interactions from OGIR have been coded. Not all interactions observed at the Group Buijs have been coded. I have taken the observed interactions from a period of five successive weeks, so that a comparable amount of episodes was gathered from both organizations.

Scores were attributed as follows. Each episode was attributed to one type of origination by coding it one the three dimensions. If a certain type of move occurs within an episode, no matter how often, it received a score of one. If not, it received a score of zero. If one of the subtypes of effects was found in an episode, a score of one on that subtype was attributed to that episode. If not, a score of zero was attributed. The scores on the main types of effect (as presented in Table 6.1) were determined on the basis of the scores on its subtypes. If one or more of its subtypes were present, I scored a one. If none of its subtypes was present, a zero was scored for that main type of effect. The strength of an effect was not coded. Coded effects always relate to alter. Effects related to ego, the speaker or writer, were not coded. But something is said about effect pertaining to ego in the discussion of 'self-suggesting'.

Appendix 6: Origination mechanisms and moves

	reporting about others	describing own activities	describing own knowledge	describing own problem	describing findings or theory	describing earlier interaction	describing experiment	describing own results	describing technology	hypothesizing	suggesting technical solution	suggesting experiment	suggesting new research	warning	instructing
existing, ego, not problemoriented	8 (+6)	14 (+9)	0 (-1)	2	5 (+3)	1	1	10 (+6)	1	0 (-2)	0 (-2)	0 (-1)	1 (-1)	0	0
existing, ego, problem alter	4 (+2)	1 (-3)	0 (-1)	0 (-2)	4 (+2)	1	5 (+4)	2 (-2)	3 (+2)	1 (-1)	2	0 (-1)	2 (+1)	1 (+1)	4 (+4)
existing, ego, problem ego	2 (-4)	20 (+8)	2 (-1)	20 (+14)	3 (-3)	1 (-1)	2 (-1)	20 (+10)	1 (-2)	3 (-2)	2 (-3)	1 (-2)	2 (-2)	0 (-1)	2 (+1)
existing, ego, shared problem	2 (-1)	3 (-2)	1	0 (-3)	5 (+2)	1	2 (+1)	5	3 (+1)	3 (+1)	4 (+2)	1	3 (+1)	1 (+1)	4 (+4)
existing, alter, not problemoriented	3 (+2)	5 (+3)	1 (+1)	0 (-1)	3 (+2)	0	1 (+1)	2	1	0 (-1)	0 (-1)	0	0 (-1)	0	0
existing, alter, problem alter	1	1 (-1)	1	0 (-1)	4 (+3)	0	1	0 (-2)	3 (+2)	0 (-1)	1	0 (-1)	0 (-1)	0	2 (+2)
existing, alter, problem ego	1	2	0	2 (+1)	0 (-1)	0	0	1	2 (+2)	1	0 (-1)	0	0 (-1)	0	1 (+1)
existing, alter, shared problem	1 (+1)	0 (-1)	0	0	1 (+1)	1 (+1)	0	0 (-1)	1 (+1)	0	0	0	0	0	0
existing, management, not problemoriented	2 (+1)	3 (+1)	2 (+2)	2 (+1)	0 (-1)	0	0	2 (+1)	0	1	1	0	0 (-1)	0	0
existing, management, problem alter	0	0	0	0	0	1 (+1)	0	0	0	0	0	0	0	0	0
existing, management, shared problem	0	1 (+1)	0	0	0	0	0	1 (+1)	0	0	0	0	0	0	0
new, ego, not problemoriented	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
new, ego, problem alter	2 (-4)	0 (-11)	4 (+1)	0 (-6)	1 (-5)	1 (-1)	0 (-3)	1 (-9)	0 (-3)	9 (+4)	9 (+4)	7 (+4)	3 (-1)	2 (+1)	3 (+2)
new, ego, problem ego	0 (-1)	1 (-1)	2 (+1)	0 (-1)	0 (-1)	0	0 (-1)	0 (-2)	0 (-1)	2 (+1)	1	0 (-1)	1	0	0
new, ego, shared problem	0 (-1)	1 (-2)	0 (-1)	0 (-1)	0 (-1)	0	0 (-1)	1 (-1)	0 (-1)	0 (-1)	3 (+2)	3 (+2)	4 (+3)	0	1 (+1)
new, alter, problem ego	0	0	0	0	0	0	0	0	0	1 (+1)	0	0	0	0	0
total	26	52	13	26	26	7	12	45	15	21	23	12	16	4	17

continued -

	referring to person	referring to literature / interaction	giving arguments	agreeing	rejecting	concluding	redescribing and summarizing	asking a question	questioning	asking for help	showing	handing over publications	on the spot calculating / trying	expressing observation	total
existing, ego, not problemoriented	0 (-1)	3 (-2)	1 (-2)	0 (-2)	0 (-2)	0 (-1)	0 (-1)	2 (-3)	0 (-1)	0 (-1)	1	0	0 (-1)	0 (-1)	50
existing, ego, problem alter	3 (+2)	2 (+1)	1 (-2)	0 (-2)	1 (-1)	2 (+2)	0 (-1)	2 (-2)	0 (-1)	0 (-1)	2 (+1)	0	0 (-1)	0	43
existing, ego, problem ego	0 (-2)	0 (-2)	3 (-5)	0 (-5)	2 (-2)	2 (+1)	1 (-1)	15 (+3)	1 (-1)	7 (+5)	6 (+4)	2 (+1)	0 (-2)	1	121
existing, ego, shared problem	0 (-1)	1	5 (+1)	2	1 (-1)	2 (+1)	1	4 (-1)	0 (-1)	1	0 (-1)	0	1	0 (-1)	56
existing, alter, not problemoriented	0	0	1	1	1	0	0	0 (-2)	0	0	1 (+1)	0	0	0	20
existing, alter, problem alter	2 (+2)	1 (+1)	1 (-1)	1	1	0	0	1 (-1)	0	0	0	1 (+1)	1 (+1)	0	23
existing, alter, problem ego	0	0	2 (+1)	2 (+1)	2 (+1)	0	0	1 (-1)	0	0	0	0	0	0	17
existing, alter, shared problem	0	0	0	1 (+1)	1 (+1)	0	0	0 (-1)	0	0	0	0	0	0	6
existing, management, not problemoriented	0	0	1	1	0 (-1)	1 (+1)	0	0 (-2)	0	1 (+1)	0	0	0	0	17
existing, management, problem alter	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
existing, management, shared problem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
new, ego, not problemoriented	0	0	0	0	0	0	0	3 (+3)	0	0	0	0	0	0	3
new, ego, problem alter	2	1 (-1)	16 (+8)	10 (+5)	7 (+3)	11 (+10)	5 (+3)	15 (+4)	6 (+4)	0 (-2)	0 (-2)	0 (-1)	1 (-1)	1	117
new, ego, problem ego	0	0	4 (+2)	3 (+1)	2	2 (+2)	0	4 (+2)	0	0	0	0	1 (+1)	2 (+2)	25
new, ego, shared problem	0	0	2	1	1	3 (+3)	0	4 (+1)	0	0	0 (-1)	0	3 (+3)	2 (+2)	29
new, alter, problem ego	0	0	0	0	0	0	0	1 (+1)	0	0	0	0	1 (+1)	0	3
total	7	8	37	22	19	23	7	52	7	9	10	3	8	6	533

Appendix 7: Origination mechanisms and subtypes of effects

	new problem	structuring problem	new technical solution	new explanation or theory	new data or observations	new experiment or experimental ability	change of justication	formation or change of degree of belief	future communication	thinking about problem	measuring	trying / using experiment	trying / using technical solution	questions / interests background knowledge	development of background knowledge
existing, ego, not problemoriented	0 (-2)	0 (-1)	0 (-2)	1	1	0 (-1)	1 (-1)	1 (-2)	4 (+2)	0 (-1)	0 (-1)	0 (-1)	0 (-1)	1 (+1)	7 (+4)
existing, ego, problem alter	3 (+2)	2 (+1)	0 (-2)	3 (+2)	3 (+2)	2 (+1)	4 (+2)	4 (+5)	2	0 (-1)	1	1	1 (+1)	1 (+1)	4 (+2)
existing, ego, problem ego	2 (-2)	0 (-3)	1 (-4)	1 (-2)	0 (-4)	0 (-2)	1 (-5)	0 (-3)	5 (-1)	2	3 (+1)	0 (-3)	0 (-2)	1	8 (+1)
existing, ego, shared problem	4 (+2)	2 (+1)	2	2 (+1)	1	1 (-1)	2	3 (+3)	4 (+2)	2 (+1)	1	2 (+1)	0 (-1)	1 (+1)	1 (-1)
existing, alter, not problemoriented	0 (-1)	0	0 (-1)	0	0	0	0 (-1)	0 (-1)	0 (-1)	0	0	0	0	0	3 (+2)
existing, alter, problem alter	0 (-1)	0 (-1)	3 (+2)	0 (-1)	4 (+3)	3 (+2)	3 (+2)	5 (+3)	2 (+1)	1	0 (-1)	2 (+1)	2 (+2)	0	0 (-2)
existing, alter, problem ego	0 (-1)	0	0 (-1)	0	0	0	0 (-1)	0 (-1)	0 (-1)	0	0	0	0	0	1
existing, alter, shared problem	0	0	1 (+1)	0	0	0	0	2 (-1)	1 (+1)	0	0	0	0	0	0
existing, management, not problemoriented	0	0	1 (+1)	0	0	0	0	0 (-1)	0	0	0	0	1 (+1)	0	0 (-1)
existing, management, problem alter	0	1 (+1)	0	0	0	0	0	0	0	0	0	0	0	0	0
existing, management, shared problem	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1 (+1)
new, ego, not problemoriented	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
new, ego, problem alter	4 (+1)	3 (-1)	10 (+6)	4 (+2)	2 (-1)	1 (-1)	8 (+4)	14 (+8)	4	2	3 (+1)	4 (+2)	2 (+1)	0 (-1)	0 (-5)
new, ego, problem ego	0 (-1)	0	0 (-1)	0	1 (+1)	0	0	0 (-1)	0 (-1)	0	0	0	0	0	1
new, ego, shared problem	4 (+3)	3 (+2)	2 (+1)	1	2 (+1)	1 (+1)	3 (+2)	4 (+2)	0 (-1)	1 (+1)	0	3 (+2)	0	0	0 (-2)
new, alter, problem ego	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
t0tal	17	11	20	12	14	8	22	33	22	8	8	12	6	4	26

- continued -

	questions / interests in others	knowledge about activities of others	knowledge about problems of others	knowledge about knowledge of others	knowledge about literature / interactions	activating within interaction	changing degree of consensus	no effect	**total**
existing, ego, not problemoriented	3 (+1)	16 (+10)	2 (-3)	4 (+2)	3 (+2)	9 (-2)	0 (-2)	0	53
existing, ego, problem alter	0 (-2)	4 (-1)	0 (-4)	2	2 (+1)	3 (-6)	0 (-2)	0	42
existing, ego, problem ego	11 (+6)	16 (+2)	31 (+19)	3 (-2)	2 (-1)	41 (+14)	1 (-4)	2 (+1)	131
existing, ego, shared problem	1 (-1)	1 (-4)	1 (-3)	1 (-1)	1	10 (+1)	2	0	45
existing, alter, not problemoriented	2 (+1)	8 (+6)	2	0 (-1)	0	2 (-2)	1	0	18
existing, alter, problem alter	0 (-1)	3 (-1)	0 (-3)	4 (+3)	1	1 (-6)	0 (-1)	0	34
existing, alter, problem ego	2 (+1)	4 (+2)	6 (+5)	0 (-1)	0	2 (-1)	0 (-1)	0	15
existing, alter, shared problem	0	1	0 (-1)	0	1 (+1)	3 (+1)	0	0	9
existing, management, not problemoriented	1 (+1)	3 (+2)	2 (+1)	0	0	2	0	0	10
existing, management, problem alter	0	0	0	0	0	0	0	0	1
existing, management, shared problem	0	0	0	0	0	0	0	0	1
new, ego, not problemoriented	0	0	0	0	0	3 (+2)	0	0	3
new, ego, problem alter	0 (-4)	0 (-11)	0 (-9)	5 (+1)	0 (-2)	17 (-3)	11 (+7)	1	95
new, ego, problem ego	1	0 (-2)	3 (+2)	1	0	7 (+4)	2 (+1)	0	16
new, ego, shared problem	0 (-1)	0 (-3)	0 (-3)	0 (-1)	0 (-1)	4 (-2)	2 (+1)	0	30
new, alter, problem ego	0	0	0	1 (+1)	0	2 (-1)	0	0	3
total	21	56	47	21	10	106	19	3	506

Appendix 8: Origination mechanisms and direct/indirect contributions

	number of cases	*direct contributions*	*indirect contributions*
existing, ego, not problemoriented	26	5	23
existing, ego, problem alter	18	12	8
existing, ego, problem ego	54	12	38
existing, ego, shared problem	20	15	4
existing, alter, not problemoriented	8	0	8
existing, alter, problem alter	16	13	6
existing, alter, problem ego	7	0	7
existing, alter, shared problem	5	3	2
existing, management, not problemoriented	3	1	3
existing, management, problem alter	1	1	0
existing, management, shared problem	1	0	1
new, ego, not problemoriented	3	0	0
new, ego, problem alter	37	26	5
new, ego, problem ego	12	1	5
new, ego, shared problem	14	12	0
new, alter, problem ego	2	0	1
total	227	101	111

SUMMARY

Over the past decade, the field of organization studies has increasingly focused on knowledge and knowledge processes in organizations. This thesis describes a study of one of those processes, knowledge sharing, in the context of industrial research. Though the attention for knowledge in organizations is rather new, technical communication in industrial research has been subject of research for over the last fifty years (e.g., Herner 1954; Allen 1977; Tushman 1978; Keller 1994). One major lesson that can be learned from past research is that technical communication contributes to research performance. In a study of 1311 researchers from industry and government laboratories, Pelz and Andrews (1966) already found a significant correlation between a researcher's performance and his communication with colleagues within and outside his group. Recently Anderson et al. (2001) established again that colleagues are the most important source of information for researchers (after the use of their own knowledge).

Although the importance of technical communication has been confirmed over and over again, we do not know very much about the details of the contribution of technical communication to industrial research practices. With a few exceptions (Johnston and Gibbons 1975; Faulkner and Senker 1995), the content of technical communication has not been systematically studied. Nevertheless, inspired by linear communication models (e.g., Shannon and Weaver 1949), most studies in the field have interpreted technical communication as the transfer of information or knowledge (e.g., Gerstenfeld en Berger 1980; Kogut en Zander 1992; Moenaert en Caeldries 1996). Furthermore, the way in which technical communication is accomplished, is not systematically explored. Most of the things researchers might say will be irrelevant for the work of others. Nevertheless researchers manage to contribute to each others work. Several authors assume that this is because communication is initiated by those in need of information or knowledge (e.g., Leckie et al. 1996; Hansen 1999). Past research has found many factors that enable or constrain knowledge sharing (e.g., Szulanski 1996; van der Bij et al. 2003), but these studies did not yield insight in the ways in which communication is realized. The first objective of the study reported in this dissertation was to gain insight in these issues: in what ways does technical communication contribute to industrial research practices and how is this accomplished.

This study had an important theoretical objective as well. Within the field of organization studies two theoretical perspectives have offered an explanation for the value of technical communication. These are the information processing approach (Galbraith 1973; 1977; Tushman and Nadler 1978; Daft and Lengel 1986) and the knowledge-based theory of the firm (Kogut and Zander 1992; 1996; Grant 1996a; 1996b; 2001). According to the information processing approach (IPA), organization members face uncertainty and ambiguity, caused by task characteristics, task interdependencies and the organizational environment. Furthermore, the IPA assumes, in line with others, that technical communication consists of information transfer, making it capable of reducing uncertainty and ambiguity. The central hypothesis of the IPA is that higher performing organizations match their actual information processing to the information processing needs associated with the degrees of uncertainty and ambiguity they face. Thus, the core of the explanation for the value of technical communication is that it is capable of reducing uncertainty or ambiguity by transferring information.

Recently, the knowledge-based theory of the firm (KBT) has been developed. This theory starts from the observation that a fundamental asymmetry exists between knowledge development and knowledge application (Demsetz 1991). To develop a thorough knowledge base, individuals have to specialize. However, to produce or develop complex products, a broad range of knowledge is necessary. Therefore, according to the KBT, the performance of an organization depends upon the integration of the specialized knowledge of individuals, that is, upon the coordinated application of this knowledge. The KBT, and the literature on knowledge management, interprets technical communication first and foremost as knowledge transfer. Knowledge transfer is interpreted as one among a number of possible knowledge integration mechanisms. In this way the KBT offers an explanation of the value of communication as well. However, the explanations of the IPA and the KBT are not based on detailed investigations of the content and process of technical communication. Van de Ven and Drazin (1985) note that the IPA uses information as an abstract, latent, unmeasured variable. Grant (1996a; 1996b) calls for detailed empirical research on knowledge sharing and knowledge integration to enhance his theoretical analyses. Therefore, the second objective of this study was to use empirical research results to reflect critically upon the assumptions and explanations of the IPA and the KBT.

The objectives of this study called in the first place for exploratory, empirical research. Past studies have emphasized that communication should be studied within the context of the situated practices of group members (Lynch 1985; Orr 1990; Knorr-Cetina 1995). For that reason, a choice was made to study communication among researchers by close observation. This was done in ethnographic studies within a group of Philips Research Laboratories and within a research group at Shell Global Solutions. Within these research groups, interactions were observed, tape-recorded and discussed with those involved. This was partly accomplished by shadowing seven researchers, each for a few days. Interviews were held and documents were studied. The resulting data were analyzed using the grounded theory approach (Glaser and Strauss 1967; Glaser 1978). The grounded theory approach is a structured way of crafting theory out of especially qualitative data. These qualitative analyses were followed by additional quantitative analyses.

The main empirical findings of the study were the following. First, a taxonomy of research-related effects of communication was constructed. The effects of communication were divided in direct contributions and indirect contributions. Those effects that are directly of use in the research process were labelled direct contributions. These include the development and change of research problems, contributing to a solution and activating to undertake particular actions. Indirect contributions may be of later use, for example for future communication. These include the development of knowledge about others and the development of background knowledge. Each of these different types of effects was divided in subtypes. For example, the main type 'contributing to a solution' encompasses four types of possible solutions, the increase of justification and changing the degree of belief in a solution.

Second, a taxonomy of 'moves' was created. This concept is partly derived from speech act theory (Searle 1969). A move is a specific act within communication. A total of 29 different research-related moves were discerned. Examples are 'describing own problem', 'describing own results', 'hypothesizing', 'agreeing', 'questioning', 'asking' and 'on the spot calculating / trying'. A comparison with existing taxonomies (Johnston and Gibbons 1975; Okada and Simon 1997) showed that the developed taxonomy is a substantial improvement.

Besides these taxonomies, the concept of 'origination mechanisms' was developed. This three-dimensional concept refers to the way in which the content of technical communication is realized. Its three dimensions pertain to (1) whether the content is selected from existing content or developed anew within the interaction; (2) whether the selection or development process is directed by ego (the speaker / writer), alter (the hearer / reader) or management; and (3) whether this process is oriented at ego's problem, alter's problem, a shared problem or is not oriented at a particular problem at all. Combining these three dimensions yields 24 logically possible origination mechanisms, of which 16 were found in the data. Examples of these origination mechanisms are:

- 'diffusing': ego selecting existing information without an orientation at a specific problem
- 'pushing': ego selecting existing information oriented at a problem of alter
- 'pulled origination': existing information is asked by alter
- 'thinking along': ego develops new content oriented at a problem of alter
- 'self-suggesting': ego develops new content oriented at one of his own problems within an interaction

It should be noted that one interaction is often characterized by more than one origination mechanism. This holds especially for interactive communication. Quantitative analyses showed that these origination mechanisms are associated with different moves and effects. For example, 'diffusing' is associated with the description of own activities and own results, and reporting about others. Out of 26 cases (in a total 227) in which this mechanism was found, 23 yielded an indirect contribution and only 5 a direct contribution. Conversely, 'thinking along' is predominantly associated with moves like giving arguments, suggesting experiments and technical solutions, agreeing, rejecting, questioning and concluding. Thinking along yielded a direct contribution in 26 out of 37 cases.

The concept of origination mechanisms is a contribution to the existing literature. Only fragments of it have been acknowledged before, such as the distinction between 'pushing' and 'pulling' (e.g., Langrish et al. 1972; Schulz 2001). Furthermore, it enables the identification of biases in the existing literature. For example, most literature on information transfer assumes that this information is always existing before communication, waiting to be transferred. Another bias in the existing literature is that it assumes that information transfer and knowledge transfer are initiated by information searching individuals.

A general finding with regard to origination mechanisms is that those origination mechanisms that are oriented at a problem of alter or a shared problem are most likely to yield direct contributions (in 82 out of 112 cases). Nevertheless, direct contributions are also produced via originations that are not oriented at such a problem and by self-suggesting: thinking up new ideas with regard to one's own problem in interaction. The effectiveness of origination mechanisms oriented at a shared problem or a problem of alter depends upon the application and development of knowledge. For example, asking a targeted question is enabled by knowing what knowledge one is lacking and by knowing who has that knowledge. For thinking along that is not necessary. But thinking along requires that ego knows about alter's problem and has relevant background knowledge. Each of the origination mechanisms has its conditions for effective employment. Therefore it is not wise to limit communication to one or a few mechanisms.

These empirical results were used to reflect upon the theoretical explanations of the value of technical communication offered by the IPA and the KBT. With regard to the IPA, the following conclusions were drawn. First, a reflection upon the effects of technical communication showed that technical communication does not always reduce uncertainty or ambiguity, as is assumed by the IPA. Communication also leads to new questions and problems, to vanishing certainties and to conflicting interpretations. The increase of uncertainty or ambiguity may be valuable effects of technical communication in research as well. The assumption that technical communication can be interpreted as information transfer is questionable too. Several interpretations of 'information' were discussed (e.g., Shannon and Weaver 1949; Dretske 1981). For example, if information is interpreted as a capacity to reduce uncertainty or to increase knowledge (like Galbraith (1973) and Tushman and Nadler (1978) assume), the assumption that useful technical communication can be interpreted as information transfer is false. Both conclusions undermine the core of the explanation of the value of communication by the IPA.

The KBT interprets technical communication as knowledge transfer, and knowledge transfer as a knowledge integration mechanism. According to this perspective, the integration of knowledge determines the performance of firms. However, a reflection upon moves and effects showed that useful technical communication cannot always be interpreted as knowledge transfer. Some instances of technical communication are better described as 'knowledge conducive communication'. Moreover, in contrast with existing views, knowledge application and knowledge generation play a central role in technical communication as well. But, in fact, this strengthens the explanation of the KBT. The analysis of knowledge processes occurring in technical communication shows other ways of integrating knowledge. For example, in thinking along ego applies his knowledge to a problem of alter. In one of the studied episodes, an expert in fracture mechanics applied his knowledge to determine the cause of a broken disc, showed to him by a colleague. The expert communicated his conclusion but did not communicate all knowledge on fracture mechanics that he used. This form of knowledge integration, temporarily applying one's knowledge to somebody else's problem, is more efficient than knowledge transfer, since not all knowledge that gets integrated needs to be transferred. Thus, a number of origination mechanisms that are effective in yielding direct contributions, including thinking along, are efficient as well. Further, the discovery of this knowledge integration mechanism shows the incompleteness of the taxonomy of mechanisms developed by Grant (1996b; 1997).

Insight in the effectiveness and efficiency of the origination mechanisms in which ego selects or develops with an eye on a problem of alter or a shared problem was furthered by interpreting research findings in terms of distributed cognition (Hutchins 1995). In these origination mechanisms, including thinking along, a particular distribution of cognitive labor is realized. The temporary distribution of the cognitive labor over more people, for example during an interactive presentation, improves creativity and reliability (probably in an efficient way). Finally this study indicated that the value of this form of integrated cognitive work is not limited to cases in which a need for task integration exists. That suggests that the focus on the integration of knowledge and cognition is a valuable addition to the traditional orientation on the integration of tasks and not just a semantical shift.

The research results provide a new explanation for the specific value of personal communication. Existing explanations include that some information cannot be found in published sources or databases (Holland et al. 1976), that personal communication is a richer communication medium (Daft and Lengel 1986) and that personal communication enables the transfer of tacit knowledge (Nonaka 1994). This study suggests that personal communication enables those origination mechanisms in which content is selected or developed by ego with an orientation at a problem of alter or a shared problem. Enabled by the application of knowledge, these origination mechanisms yield effective and efficient contributions to research practices. Finally, it can be concluded that technical communication is a heterogeneous, active and integral part of industrial research practices. These characteristics are insufficiently captured by interpretations of technical communication as information transfer or knowledge transfer.

SAMENVATTING

De afgelopen jaren is in de organisatiekunde meer en meer belangstelling ontstaan voor kennis en kennisprocessen in organisaties. Dit proefschrift beschrijft een onderzoek naar één van die processen, kennisdeling, binnen industriële onderzoekslaboratoria. Alhoewel de aandacht voor kennis in organisaties relatief recent is, wordt communicatie tussen onderzoekers al meer dan vijftig jaar onderzocht (e.g, Herner 1954; Allen 1977; Tushman 1978; Keller 1994). Een belangrijke les uit dat onderzoek is dat communicatie bijdraagt aan de prestatie van onderzoekers (Allen 1977). In een studie naar het communicatiegedrag van 1311 onderzoekers in industriële en overheidslaboratoria vonden Pelz en Andrews (1966) reeds een significante correlatie tussen de prestaties van onderzoekers en de intensiteit van hun communicatie met collega's binnen en buiten de eigen groep. Recentelijk stelden Anderson et al. (2001) nogmaals vast dat collega's de belangrijkste informatiebron zijn van onderzoekers (na hun eigen kennis).

Ondanks het feit dat het belang van communicatie met collega's regelmatig is vastgesteld, weten we nog relatief weinig van de manier waarop communicatie precies bijdraagt aan het werk van onderzoekers. Op een enkele uitzondering na (Johnston en Gibbons 1975; Faulkner en Senker 1995), is de inhoud van onderzoeksgerichte communicatie niet systematisch in kaart gebracht. Desalniettemin hebben veel studies, mede geïnspireerd door lineaire communicatiemodellen (e.g., Shannon en Weaver 1949), communicatie geduid als de overdracht van informatie of kennis (e.g., Gerstenfeld en Berger 1980; Kogut en Zander 1992; Moenaert en Caeldries 1996). Daarnaast is ook de manier waarop communicatie wordt gerealiseerd niet systematisch onderzocht. De meeste dingen die onderzoekers tegen elkaar zouden kunnen zeggen, dragen niet direct bij aan elkaars onderzoek. Toch weten onderzoekers wel te bewerkstelligen dat hun communicatie nuttig is. Regelmatig wordt er vanuit gegaan dat dit komt doordat communicatie wordt geïnitieerd door iemand die zoekt naar bepaalde kennis of informatie (e.g., Leckie et al. 1996; Hansen 1999). Eerdere onderzoeken hebben wel veel factoren gevonden die kennisdeling positief of negatief beïnvloeden (e.g., Szulanski 1996; van der Bij et al. 2003), maar deze onderzoeken hebben weinig inzicht opgeleverd in de manier waarop communicatie wordt gerealiseerd. De doelstelling van het gepresenteerde onderzoek was in de eerste plaats het verkrijgen van inzicht in deze vraagstukken: op welke wijze draagt communicatie bij aan het werk van onderzoekers en hoe wordt dit gerealiseerd.

Het onderzoek had daarnaast echter ook een belangrijke theoretische doelstelling. In de organisatiekunde bieden twee theoretische perspectieven een verklaring voor de waarde van technische communicatie. Dit zijn de *information processing approach* (Galbraith 1973; 1977; Tushman en Nadler 1978; Daft en Lengel 1986) en de *knowledge-based theory of the firm* (Kogut en Zander 1992; 1996; Grant 1996a; 1996b; 2001). Volgens de information processing approach (IPA) worden organisatieleden geconfronteerd met onzekerheid en ambiguïteit, voortvloeiend uit hun taken, de afhankelijkheid van andere taken en de omgeving van de organisatie. Vervolgens veronderstelt de IPA, in lijn met anderen, dat communicatie bestaat uit het overdragen van informatie en dat deze informatie bestaande onzekerheid en ambiguïteit kan reduceren. De centrale hypothese van de IPA is dat in goed presterende organisaties de hoeveelheid informatieoverdracht is afgestemd op de aanwezige onzekerheid en ambiguïteit. De kern van de verklaring voor de waarde van communicatie is dus dat het onzekerheid en ambiguïteit kan reduceren, doordat in communicatie informatie wordt overgedragen.

Meer recent is de *knowledge-based theory of the firm* (KBT) ontwikkeld. Deze theorie begint met de constatering dat er een fundamentele asymmetrie bestaat tussen kennisontwikkeling en kennistoepassing (Demsetz 1991). Om diepgaande kennis te ontwikkelen moeten individuen zich specialiseren. Om een complex product te ontwikkelen of te produceren is echter veel verschillende kennis nodig. Volgens de KBT zijn de prestaties van een organisatie daarom afhankelijk van de integratie van de gespecialiseerde kennis van individuen, dat wil zeggen, van de gecoördineerde toepassing van die kennis. De KBT, en de literatuur over kennismanagement, interpreteert communicatie over het algemeen als kennisoverdracht. Kennisoverdracht is één van de mogelijke manieren waarop kennis geïntegreerd kan worden. Daarmee biedt de KBT ook een verklaring voor de waarde van communicatie. Deze theoretische interpretaties en verklaringen van de KBT en de IPA zijn echter niet gebaseerd op gedetailleerde bevindingen ten aanzien van technische communicatie. Van de Ven en Drazin (1985) merken op dat de IPA het concept informatie hanteert als een abstracte, ongemeten of latente variabele. Grant (1996a; 1996b) stelt dat diepgaand empirisch onderzoek naar kennisdeling en kennisintegratie nodig is om zijn theoretische analyse verder te ontwikkelen. De tweede doelstelling van het huidige onderzoek was daarom om op grond van bevindingen uit het empirische deel van het onderzoek kritisch te reflecteren op de assumpties en verklaringen van de IPA en de KBT.

De doelstellingen van dit onderzoek vroegen in de eerste plaats om exploratief empirisch onderzoek. Eerder onderzoek heeft benadrukt dat communicatie moet worden bestudeerd als onderdeel van de gesitueerde praktijken van groepsleden (Lynch 1985; Orr 1990; Knorr-Cetina 1995). Daarom is er in dit onderzoek voor gekozen om technische communicatie van nabij te observeren. Dat is gedaan middels etnografische studies in een onderzoeksgroep van Philips Research Laboratories en in een onderzoeksgroep van Shell Global Solutions. In deze twee onderzoeksgroepen zijn interacties tussen onderzoekers geobserveerd, op band opgenomen en voor- en nabesproken met de betrokkenen. Daartoe zijn zeven onderzoekers meerdere dagen geschaduwd. Verder zijn er interviews afgenomen en zijn documenten bestudeerd. De onderzoeksgegevens zijn geanalyseerd volgens de gefundeerde theorie benadering (Glaser and Strauss 1967; Glaser 1978). Dat is een gestructureerde werkwijze gericht op de ontwikkeling van theorie op grond van met name kwalitatieve onderzoeksgegevens. Deze kwalitatieve analyses zijn later gevolgd door kwantitatieve analyses.

De resultaten van het empirische onderzoek zijn als volgt. In de eerste plaats is een taxonomie van effecten van communicatie tussen onderzoekers ontwikkeld. De effecten van technische communicatie zijn onderverdeeld in directe bijdragen en indirecte bijdragen. Directe bijdragen zijn effecten die direct van nut zijn in het onderzoeksproces. Dit zijn het ontwikkelen en veranderen van problemen, het bijdragen aan een oplossing en het aanzetten tot bepaalde handelingen. Indirecte bijdragen kunnen van later nut zijn, bijvoorbeeld voor toekomstige communicatie. Dit betreft met name het verkrijgen van kennis over het werk van anderen en het verkrijgen van achtergrondkennis. Deze verschillende typen effecten zijn elk verder onderverdeeld in verschillende subtypen. Het type ‘bijdrage aan een oplossing’ omvat bijvoorbeeld vier soorten mogelijke oplossingen, het verkrijgen van argumenten en het aanpassen van de mate van geloof in een oplossing.

In de tweede plaats is een taxonomie van ‘zetten’ (‘*moves*’) ontwikkeld. Dit begrip is mede gebaseerd op het concept ‘speech act’ van Searle (1969). Een zet is een specifieke handeling die iemand voltrekt in communicatie. In totaal zijn in dit onderzoek 29 onderzoeksgerelateerde zetten onderscheiden. Voorbeelden zijn ‘beschrijven eigen probleem’, ‘beschrijven eigen resultaten’, ‘hypothetiseren’, ‘instemmen’, ‘ter discussie stellen’, ‘vragen’ en ‘ter plekke uitproberen / uitrekenen’. Een vergelijking met bestaande taxonomieën (Johnston en Gibbons 1975; Okada en Simon 1997) laat zien dat de ontwikkelde taxonomie een substantiële verbetering inhoudt.

Naast deze taxonomieën is het concept ‘wordingsmechanisme’ (‘*origination mechanism*’) ontwikkeld. Dit verwijst naar de manier waarop de inhoud van communicatie tot stand komt. Het concept is gebaseerd is op drie onderliggende dimensies: (1) is de inhoud geselecteerd uit bestaande informatie of nieuw ontwikkeld in de interactie?; (2) is dat proces gestuurd door ego (de spreker / schrijver), alter (de luisteraar / lezer) of door management?; (3) is dat proces gericht op een probleem van ego, een probleem van alter, een gedeeld probleem of is het niet gericht op een specifiek probleem? Als deze drie dimensies worden gecombineerd, levert dat 24 mogelijke wordingsmechanismen op. Zestien daarvan zijn in de onderzoekgegevens gevonden. Voorbeelden daarvan zijn:

- 'verspreiden': bestaande informatie die door ego wordt geselecteerd zonder zich op een specifiek probleem te richten
- '*pushing*': bestaande informatie die door ego wordt geselecteerd omdat hij denkt dat het van belang is voor een probleem van alter
- '*pulled origination*': bestaande informatie wordt door alter gevraagd
- 'meedenken': ego bedenkt iets nieuws, gericht op een probleem van alter
- 'zelf-suggestie': ego bedenkt, in gesprek met een ander, iets nieuws voor een eigen probleem

Opgemerkt dient te worden dat in één interactie vaak meerdere mechanismen gebruikt worden, zeker als het interactieve communicatie betreft. Kwantitatieve analyses laten zien dat de wordingsmechanismen geassocieerd zijn met verschillende zetten en effecten. Bijvoorbeeld, 'verspreiden' is met name geassocieerd met het beschrijven van eigen activiteiten, eigen resultaten en het vertellen over anderen. Van de 26 gevallen (uit een totaal van 227) waarin dit mechanisme werd gevonden, resulteerden er 23 in een indirecte bijdrage en slechts 5 in een directe bijdrage. Daarentegen is 'meedenken' vooral geassocieerd met zetten als argumenteren, het suggereren van experimenten en technische oplossingen, instemmen, afwijzen, ter discussie stellen en concluderen. In 26 uit 37 gevallen leidde dit tot directe bijdragen.

Het idee van 'wordingsmechanismen' is een bijdrage aan de bestaande literatuur. In de bestaande literatuur zijn alleen fragmenten ervan onderkend, zoals het onderscheid tussen 'pushing' en 'pulling' (e.g., Langrish et al. 1972; Schulz 2001). Tevens maakte dit concept het mogelijk om een aantal vooringenomenheden in de literatuur aan te wijzen. Bijvoorbeeld, veel literatuur over technische communicatie gaat er van uit dat de kennis of informatie reeds bestaat voordat hij wordt overgedragen. Daarnaast wordt er ook regelmatig ten onrechte van uitgegaan dat informatie- en kennisoverdracht worden gestuurd door degene die de informatie of kennis nodig heeft.

Een algemene bevinding ten aanzien van wordingsmechanismen is dat de mechanismen die georiënteerd zijn op een probleem van alter of een gedeeld probleem het vaakst tot directe bijdragen leiden (in 82 uit 112 keer). Desalniettemin, directe bijdragen kunnen ook worden gerealiseerd door middel van wordingsmechanismen die niet gericht zijn op zo'n probleem en door zelf-suggestie: het in gesprek met een ander bedenken van nieuwe ideeën door een probleemhebber zelf. De effectiviteit van wordingsmechanismen die gericht zijn op een gedeeld probleem of een probleem van alter is afhankelijk van de toepassing en ontwikkeling van kennis. Bijvoorbeeld, om een gerichte vraag te stellen is het nodig om een idee te hebben van datgene dat men zou willen weten en een idee over wie dat zou kunnen weten. Voor 'meedenken' is dat niet nodig. Daarvoor is het echter wel nodig dat ego weet heeft van een probleem van alter en over relevante achtergrondkennis beschikt. Elk van de mechanismen heeft zo zijn eigen voorwaarden voor effectieve toepassing. Vandaar dat het onverstandig is om volledig op één of enkele mechanismen te vertrouwen.

De empirische bevindingen zijn gebruikt om te reflecteren op de IPA en de KBT, het tweede doel van dit onderzoek. Met betrekking tot de IPA zijn onder andere de volgende conclusies getrokken. Ten eerste laat een reflectie op de effecten van technische communicatie zien dat communicatie niet altijd onzekerheid of ambiguïteit reduceert, zoals wordt verondersteld door de IPA. In communicatie worden ook problemen gegenereerd, worden zekerheden losgelaten, ontstaan strijdige interpretaties. Dat wil zeggen dat juist het verhogen van onzekerheid of ambiguïteit ook een nuttig effect van communicatie kan zijn. Ook de aanname dat nuttige communicatie kan worden geïnterpreteerd als informatieoverdracht is problematisch. Daartoe zijn verschillende interpretaties van informatie kritisch bevraagd (e.g., Shannon en Weaver 1949; Dretske 1981). Bijvoorbeeld, als informatie wordt geïnterpreteerd als datgene dat onzekerheid kan verlagen of kennis kan vergroten (zoals Galbraith (1973) en Tushman en Nadler (1978) stellen), is de stelling dat nuttige communicatie bestaat uit informatieoverdracht niet houdbaar. Dit tast de kern van de verklaring van het nut van communicatie door de IPA aan.

De KBT interpreteert technische communicatie als kennisoverdracht, en kennisoverdracht als een kennisintegratiemechanisme. Volgens dit perspectief bepaalt de kwaliteit van kennisintegratie de prestatie van organisaties. Echter, reflecterend op zetten en effecten van communicatie is in dit proefschrift geconcludeerd dat waardevolle technische communicatie niet altijd kan worden geïnterpreteerd als kennisoverdracht. Sommige interacties kunnen beter worden geduid als 'kennis-bevorderende communicatie'. Daarnaast is in de literatuur onvoldoende erkend dat kennistoepassing en kennisontwikkeling ook een centrale rol spelen in communicatie tussen onderzoekers. Dit is echter geen probleem voor de verklaring van de KBT. Deze andere kennisprocessen zorgen namelijk voor een andere vorm van kennisintegratie. Bijvoorbeeld, in 'meedenken' past ego zijn kennis toe op een probleem van alter. In één van de interacties past een breukmechanicaexpert zijn kennis toe om voor een collega de oorzaak van een gebroken disc te achterhalen. In dit geval deelt de expert alleen zijn conclusie mee en draagt niet zijn volledige expertise over. Deze vorm van kennisintegratie, het tijdelijk toepassen van kennis op een probleem van een ander of een gedeeld probleem, is efficiënter dan alleen de overdracht van kennis, omdat niet alle kennis die wordt geïntegreerd hoeft te worden overgedragen. Een aantal van de wordingsmechanismen die effectief zijn in het bereiken van directe bijdragen, waaronder 'meedenken', is daarom ook efficiënt. Het blootleggen van dit kennisintegratiemechanisme vraagt om een aanpassing van de taxonomie van kennisintegratiemechanismen die door Grant (1996b; 1997) ontwikkeld is.

Meer inzicht in de effectiviteit en efficiency van de wordingsmechanismen waarin ego selecteert of ontwikkelt met het oog op een probleem van alter of een gedeeld probleem is verkregen door de onderzoekgegevens te interpreteren in termen van gedistribueerde cognitie (Hutchins 1995). In deze wordingsmechanismen, waaronder 'meedenken', wordt een bepaalde verdeling van denkwerk gerealiseerd. De tijdelijke verspreiding van denkwerk met betrekking tot een bepaald probleem, bijvoorbeeld tijdens een interactieve presentatie, bevordert de creativiteit en betrouwbaarheid van onderzoek (waarschijnlijk op een efficiënte manier). Tot slot wijst dit onderzoek uit dat deze vorm van overlappend denkwerk niet alleen waarde heeft als de taken van de betrokkenen van elkaar afhankelijk zijn. Dat betekent ook dat het denken over de integratie van kennis en denkwerk een substantiële en niet slechts een semantische vernieuwing is ten opzichte van het denken over taakintegratie.

De onderzoeksresultaten bieden een nieuwe verklaring voor de specifieke waarde van persoonlijke communicatie. Bestaande verklaringen zijn onder andere dat bepaalde informatie niet in publicaties en databases gevonden kan worden (Holland et al. 1976), dat persoonlijke communicatie een 'rijker' communicatiekanaal is (Daft en Lengel 1986) en dat persoonlijke communicatie ook de overdracht van impliciete kennis mogelijk maakt (Nonaka 1994). Deze studie suggereert dat persoonlijke communicatie meer ruimte biedt voor wordingsmechanismen waarin inhoud geselecteerd of ontwikkeld wordt met het oog op een probleem van alter of een gedeeld probleem. Door de toepassing van kennis in interactie zijn deze mechanismen in staat effectieve en efficiënte bijdragen te leveren aan het werk van anderen. Tot slot kan geconcludeerd worden dat communicatie een heterogeen, actief en integraal onderdeel is van het werk van onderzoekers. Deze kenmerken worden onvolledig begrepen als communicatie alleen wordt geïnterpreteerd als informatieoverdracht of als kennisoverdracht.

ABOUT THE AUTHOR

Hans Berends was born on April 22nd, 1972, in Terneuzen (the Netherlands). He obtained a Master of Science degree in Industrial Engineering and Management Science from the Eindhoven University of Technology in 1996. In addition, he studied Philosophy at Tilburg University, where he received a Master of Arts degree in 2001. After his graduation from the Eindhoven University of Technology, he worked half a year at a medium-sized stainless steel company. In 1997 he started a Ph.D. project at the department of Organization Science, faculty of Technology Management, Eindhoven University of Technology. This Ph.D. project has resulted in the present dissertation. From January 2003 on he is employed as a staff member of the department of Organization Science. His interests include knowledge management, innovation management, organization science and philosophy.

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