THE GLOBAL R&D MANAGEMENT LEARNING CYCLE:
COPING WITH KNOWLEDGE CHALLENGES IN DISTRIBUTED RESEARCH AND DEVELOPMENT

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ABSTRACT

This paper reports on a qualitative study conducted at multinational organizations' R&D departments about their process of managing knowledge in global settings. The tension between specializing units into centers of excellence, while at the same time trying to find integration opportunities in this dispersed setting, creates challenges for management. This study approaches these challenges from both a managerial and a practice based perspective to managing R&D. Using data from interviews, we illustrate these challenges, and identify management processes on how to cope with these challenges. Moreover, we present a global R&D management learning cycle, which reveals the required interrelatedness these processes have, and their learning effect on performance in time.

Key words: Specialization; Integration; Knowledge management; Research & Development; Globalization

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1. INTRODUCTION

In recent years, multinational corporations have increasingly adopted a global approach to research and development (R&D) activities, dispersing these activities across various geographically distributed units. Partly relocating the R&D function can be a response to push factors such as a lack of available talent and mounting cost pressure in organizations' home countries (Pro Inno Europe, 2007; Chung and Yeaple, 2008), and pull factors such as the availability of highly skilled science and engineering talent, and increased proximity to customer bases in overseas countries (Kuemmerle, 1997; Lewin, Massini and Peeters, 2009; Trefler, 2005; Von Zedwitz and Gassmann, 2002; Demirbag and Glaister, 2010). This dispersion of activities changes many aspects of R&D work, creating challenges with regard to managing the knowledge being created and shared in R&D processes. These challenges, and how to cope with them, are the focus of this paper.

Dispersed R&D units can be conceptualized as centers of excellence based around particular functional specializations (Frost, Birkinshaw & Ensign, 2002; Moore and Birkinshaw, 1998). As Singh (2008) argues, however, such specialization in itself is not sufficient to create added value - it is the integration of knowledge across multiple locations that can make specialization valuable. In other words, managing knowledge in global R&D involves a tension between *specialization* on the one hand, in order for specialized knowledge creation to occur, and *integration* on the other, in order for the organization to be able to benefit from the combination of the various pockets of specialized knowledge (Grant, 1996). Hence, though specialization can be seen as the motive for dispersing R&D, it is the integration between specializations that makes it successful in practice. At the same time, dispersing R&D presents challenges in achieving this integration. In this paper, we aim to provide more insight into the nature of these challenges, and into processes that management can apply to face these challenges. Hence, the question guiding our research is: "What are the main challenges organizations face in balancing specialization and integration of knowledge in global R&D settings, and how do they cope with these challenges?"

To understand what challenges are involved in making specialization and integration work, and how processes concerning these challenges coevolve, the study in this paper follows an inductive exploratory approach, based on semi-structured, in-depth interviews with managers and key informants directly involved with global R&D. Building on 15 interviews with representatives of four multinational organizations with global R&D portfolios, as well as an in-depth case analysis of one multisite R&D collaboration based on 28 interviews, we observe two main contributions from our analysis. First, where previous research has mainly approached the tension between specialization and integration from a purely managerial perspective, our findings show that the emergent nature of knowledge processes should also be taken into account. Specifically, management processes entail both top-down and bottom-up approaches, and are highly interrelated. Second, we observe an interrelatedness of these processes across space and time, and propose a dynamic model for R&D learning in dispersed settings.

The paper is organized as follows: First, we discuss the specific nature of dispersed R&D work, leading to a model identifying the major challenges in managing dispersed R&D. Based on our empirical findings, we discuss how management copes with these challenges through a number of processes, which together form the R&D management learning cycle. We illustrate this cycle with a short case analysis. The discussion section then elaborates on the two contributions of our model. Finally, we draw implications from the R&D management learning cycle for theory and practice on managing and learning in the R&D portfolio.

2. CONCEPTUAL BACKGROUND

2.1. Specialization and integration in dispersed R&D work

The development towards a more geographically dispersed setting for R&D work is often the result of a search for synergistical ways to achieve new product development (Pearce and Papanastassiou, 1996). Such synergy requires specialization on the one hand (within centers of excellence that create in-depth knowledge about a very specific domain), and integration on the other (management efforts to create some sort of shared organizational knowledge). Specializing units into centers of excellence, while at the same time trying to find integration opportunities in this dispersed setting, creates a challenging tension for management (Clark and Fujimoto, 1991; Kuemmerle, 1997). Dispersing R&D units complicates integration processes because of differences in knowledge bases, communication, ways of working, culture, and time zones. To problematize the tension in managing specialization and integration in dispersed R&D, we follow the description of R&D work by Dougherty (2001), and elaborate on it by introducing characteristics of R&D work in a dispersed setting.

Dougherty (2001) identified three central characteristics of R&D work that are helpful in defining challenges in managing the tension between integration and specialization. First, R&D work has an *integral* nature, which refers to the interrelatedness of activities needed to perform R&D. Second, R&D knowledge should be seen within its *particular* (social and practical) *context* in order to recognize problems and opportunities for innovation. Third, R&D work is characterized by the *emergent nature of standards* guiding the work. Below we elaborate why these central characteristics of R&D work enhance the tension between specialization and integration when R&D units are dispersed.

The *integral nature* of R&D refers to the interrelatedness of activities that are part of research and development. In R&D, different knowledge domains are combined to form the knowledge assets necessary for problem solving and innovation. In a colocated setting, this interrelatedness is realized by deliberate organization of activities, or routines developed through experience and time (e.g. Levitt and March, 1988). When R&D units are geographically dispersed, the distance between locations (geographical, organizational and cultural) severely reduces the interrelatedness of activities and the opportunities to combine knowledge. Furthermore, organizational routines that are developed in one location do not automatically work in the context of other locations. In conclusion, combining different knowledge domains will be much more complex in a dispersed R&D setting than in a centralized setting, and thus presents a serious management challenge.

Situated nature of R&D. R&D work is situated in a social and practical context (Tyre and von Hippel 1997), which means that the work is a process of 'learning by doing', in the physical context of use, application, or operation. The context-specific and often tacit nature of knowledge makes it impossible to share across local contexts without a sufficient degree of social interaction (Birkinshaw, 2002). Furthermore, the situated nature of R&D knowledge brings along a natural tendency for an R&D unit to specialize in its own knowledge domain. Dispersing R&D work across different local contexts increases this tendency. In order for R&D workers in a particular unit to fully understand the meaning and purpose of knowledge created in another unit, they have to understand the context in which the knowledge was created. In a dispersed R&D setting, knowledge is created and shared within different local contexts, which makes creating a shared understanding of others' knowledge much more complicated than in a centralized R&D setting.

Emergent nature of R&D. Third, R&D work is characterized by the emergent nature of working standards. This means that innovative work requires flexibility in adjusting the configuration of the process during the practice itself. The emergent nature of R&D work creates a tendency to specialize within one location, which makes it especially difficult to achieve knowledge integration when R&D is dispersed across different locations. Furthermore, when dispersing R&D activities, management often tends to prescribe and impose more process standards to compensate for a lack of shared routines. While more agreement on processes is being reached by shared standards and allocated responsibilities, flexibility of adjusting these standards and responsibilities decreases. Instead of realizing knowledge creation, this can lead to inertia in the organization's R&D processes (e.g. Tushman and O'Reilly, 2008)

Table 1. Specialization and integration in dispersed R&D

Characteristics of R&D work	Specialization/integration approaches	Problematizing dispersed R&D activities
Interrelatedness of activities, combining different knowledge domains (specializations)	Need for integration, requires relationships and rich interaction	Otherwise naturally organized processes and activities require different involved organization for collaboration.
Context bound, situated nature and a social process	Natural tendency for specialization	Lack of shared context to situate and participate in collaborative R&D work
Emergent nature of standards, experimentation and improvisation	Natural tendency for specialization, local orientation, difficult to achieve integration	Lacking flexibility to adjust configuration for R&D

In conclusion, the tension between specialization and integration which is inherent to R&D work becomes even more of an issue when R&D activities are geographically dispersed. Table 1 summarizes the arguments on which this conclusion is based.

2.2. Managing the tension between specialization and integration

Having unraveled the tension between specialization and integration in dispersed R&D, the question rises how management can cope with this tension. This question pertains to both the *focus* of management efforts (what should we manage?) and the *approach* towards managing it (how should we manage it?).

In terms of the management *focus*, a distinction can be made between managing the knowledge itself, or *content* of the work, and managing the *connections* between specialists in the network (Agterberg et al., 2010). Managing *content* in the network is complicated because the inherently situated and emergent nature of this knowledge means that direct management interventions on work content will most likely be counterproductive (Agterberg et al., 2010). On the other hand, integration of dispersed knowledge would seem to require some form of intervention. Obviously, an important challenge in balancing specialization and integration pertains to the extent to which management can and wants to intervene in this content. Managing *connections* to balance specialization and integration of knowledge between dispersed R&D units is about establishing these connections (connecting specialists and units) and creating strong ties in terms of trust, identification and such. Again, these are very challenging goals. For instance, it is likely that highly specialized units working with unique technologies will require more independence in their way of working than units with more mutuality with the organization (e.g. Cummings et al. 2003). The question that arises then is, how to establish a sufficient connection so knowledge integration between these units can take place.

The description of managing both content and connections in the previous paragraphs implicitly addresses a tension in terms of the *approach* towards managing dispersed R&D: to what extent can management really intervene, and to what extent should it want to intervene? In line with Mintzberg's (1978) distinction between intended and uninted strategies, we make a distinction between a *deliberate* versus an *emergent* approach towards managing content. A deliberate approach primarily has a top-down, planned and interventionist nature, whereas an emergent management approach is generally hands-off and facilitating. Also, a deliberate approach will primarily be aimed towards achieving integration, whereas an emergent approach is characterized by allowing specialization to occur.

The nature of R&D work as described above means that managing dispersed R&D settings requires a combination of these approaches (Puranam et al., 2009; Birkinshaw, 2002; Singh, 2008; Van den Hooff and Huysman, 2009). For example, the context-bound, social and generally emergent nature of R&D work requires an emergent approach. On the other hand, integrating different knowledge domains *across* established practices often requires more coordination and a more deliberate, integrative approach. Deliberate interventions, however, should not frustrate the emergent character of knowledge processes, but should be designed so as to facilitate these processes (Agterberg et al., 2010). For instance, establishing connections between geographically dispersed R&D units or specialist teams requires certain structures in the network, such as allocation of responsibilities and communication lines. The existence of connections, however, is a necessary but not sufficient condition for knowledge integration. The exploratory nature of R&D work usually means that there is a high degree of ambiguity and uncertainty about the knowledge to be shared between engineers, for which strong ties, characterized by trust and mutual identification, are essential (Cummings and Teng, 2003). Such ties should emerge in daily interaction between professionals sharing practices in R&D work (Brown and Duguid, 2001; Wenger, 2000).

Combining the dimensions discussed above results in four combinations from which four interrelated management challenges are identified. This conceptual model is presented in figure 1. In the remainder of this section, we will discuss these challenges in detail.

	Connections	**Content**
Deliberate approach (achieving integration)	structural embeddedness	knowledge as capital
Emergent approach (allowing specialization)	relational embeddedness	knowledge as practice

Figure 1. Challenges in managing dispersed R&D

2.3. Challenges in managing dispersed R&D

The challenge of establishing *structural embeddedness* (Granovetter 1985, Uzzi 1997) relates to establishing connections and coordination between units or sites. This largely depends on deliberate management initiatives to bring specialists or units together, explicating who knows who and who knows what. The main challenge here is determining what the optimal composition of a network would be, i.e. determining where useful contacts between individuals and units would be and where useful knowledge resides. The challenge of establishing connections in a dispersed settings is complicated because it is likely that there is no prior shared network to build on, since people at different locations do not know each other and do not meet at places such as the cafeteria or copy machine.

Relational embeddedness refers to quality and depth of connections between R&D colleagues from different units (Granovetter 1985). Establishing relational embeddedness is a challenge in terms of connections, primarily related to an emergent approach. Strong ties must emerge between people collaborating, interacting and sharing. In joint R&D projects, for example, a sufficient level of shared identity and mutual trust between specialists is required for them to share their expertise. Building relational embeddedness is a challenge because of its emergent nature, and because it requires time and exposure to the relationship, characteristics which are difficult to manage in dispersed R&D settings.

Knowledge as practice refers to the challenge of managing knowledge processes which are situated, contextual and directly related to particular practices – and thus, strongly bottom-up in nature. Knowledge integration is seen as a process that is socially constructed between sender and receiver, which is difficult to manage top-down (Blackler, 1995; Hislop 2009). Therefore, this challenge is especially complicated since the emergent character of knowledge processes makes them almost adverse to management interventions (Agterberg et al., 2010). Relational embeddedness and managing knowledge as practice are strongly related, due to their emergent and situated nature. Creating strong relations in which specialist knowledge is shared and created is an iterative and social process. This interrelatedness is shown in figure 1 by a dotted line.

Knowledge as capital: Creating 'knowledge as capital' is a challenge in terms of creating 'intellectual capital', or knowledge as an organizational "asset" (Cook and Brown, 1999). In order to take some control over knowledge in the organization, management tries to grasp some of its content, partly by making knowledge explicit, partly by making visible who knows what in the organization. In practice these are difficult tasks in a setting with specializing and dispersed units that are all involved in time-consuming innovation work. As discussed in the previous paragraph, a deliberate approach towards processes that are strongly emergent in nature creates a daunting challenge for management in balancing both approaches.

With these four challenges as a priori concepts (Eisenhardt & Graebner, 2007) we entered the analysis of the data from our interviews, in order to identify the processes involved in managing these challenges in practice. Before we discuss our empirical findings, we first provide some insight into the methods of our empirical study.

3. METHODS

Data was collected in two different settings. First, semi-structured interviews were conducted with 15 managers and key representatives of four multinational corporations with several offshore R&D affiliates. Most of the organizations were headquartered in the Netherlands and had R&D affiliates in Europe, North America and Asia. The interviews were conducted with the help of an interview protocol. The general interview protocol contained only questions regarding the position, history in the company, a typical working day, relationships between units and learning moments in working with geographically distributed R&D units. Once a general overview of the situation of the interviewees was understood, the protocol became more focused with questions regarding for example specialization and integration, and collaboration and communication between units.

Table 2: Overview of organizations and interviewees

	Company profile	Interviews
Company A	> 20.000 employees R&D Units in e.g.: The Netherlands (HQ)*, Canada Romania	R&D Director(2) Manager Team Leader Integration Manager Information Manager
Company B	>100.000 employees R&D units in e.g.: The Netherlands (HQ), China, USA, England	R&D Director Vice president Senior Vice President Scientist Department Manager
Company C	> 10.000 employees R&D units in e.g.: The Netherlands (HQ), India, USA, Poland, Australia	R&D Director Researcher Department Manager Department Manager
Company D	> 100.000 employees R&D units in e.g.: The Netherlands (HQ), China USA, India, Argentina	Knowledge manager

*R&D headquarters

The interviews, which took seventy-five minutes on average, were fully transcribed and coded in Atlas.ti. Interpretations made by the researcher of the meanings and stories told by the interviewee were discussed during the interviews, leading to a notion of mutual understanding which enhanced the quality of further levels of interpretation (Kvale, 1989). Transcription was undertaken soon after each interview, and each interview was separately reiterated during the transcription process, offering understanding of the interviewees' thoughts as well as a grasp of the organization's characteristics. During this process, concepts and constructs were identified and discussed by the researchers involved in this study. Possible constructs and concepts on factors influencing knowledge specialization and integration were proposed, however, separated from subsequent interviews in order to prevent premature or false conclusions. After transcription, the interviews were segmented and coded with Atlas.ti. From the categorizations as shown in figure 1 we identified processes between the four concepts which from the interviews appear to be challenging for management. Appendix 1 shows the codes used for the challenges and processes, their definitions and exemplary quotes.

Secondly, we conducted an analysis of a specific case of collaboration between two dispersed R&D units within one company. For this goal, 28 people involved in this collaboration were interviewed and various meetings were attended. In this paper, this case is primarily used for illustrative purposes. The main goal of the analyses in this paper is to build and support a model for managing specialization and integration of dispersed R&D. The case description serves to briefly illustrate how the dynamics of this model work in practice. The actual in-depth analysis of this case is the focus of a different paper. The 28 interviews about this case were, however, analyzed in the same way as the 15 interviews referred to above.

4. FINDINGS: THE GLOBAL R&D MANAGEMENT LEARNING CYCLE

Interviewees revealed that managing the R&D portfolio is not so much a structured process in which the end result can be determined in advance, but primarily a process of trial and error which can be seen as an organizational learning process. This learning process involves the four challenges derived from the literature, and more specifically it involves coping with these challenges in an interrelated way. From the data, four processes were derived that each help to cope with multiple challenges:

1. *Facilitating interface*, aimed at establishing structural embeddedness and enabling relational embeddedness,

2. *Situated learning*, aimed at facilitating relationships through which practices are shared and practice-based learning takes place,

3. *Knowledge integration*, aimed at balancing knowledge as practice and knowledge as capital, or translating the situated, practice based knowledge to an institutional level, and

4. *Road mapping*, aimed at implementing what is learned into new knowledge strategies and structures in the organization.

Together, the challenges and the processes developed to cope with these challenges, form the *global R&D management learning cycle*, which is depicted in figure 2. The further discussion of the findings of the interviews with the 15 key representatives from the four organizations illustrates this model, and elaborates on the interrelatedness of challenges and learning processes.

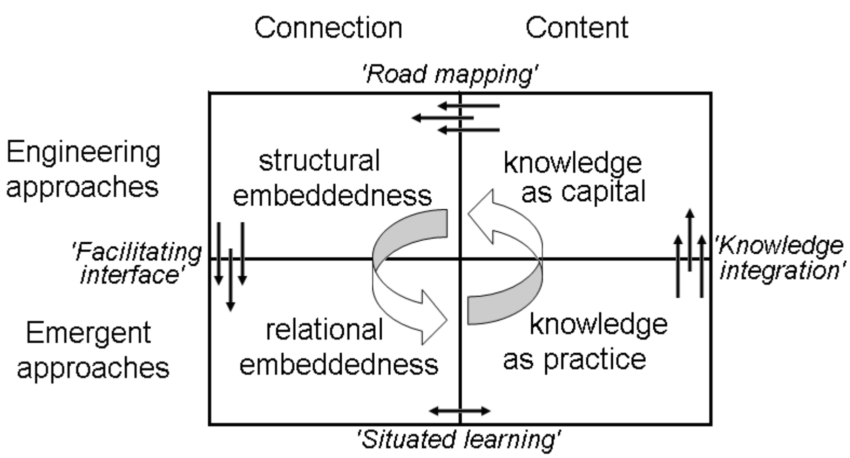

Figure 2. The Global R&D Management Learning Cycle

4.1. Facilitating Interface

Organizations face major difficulties when shifting from R&D in one location towards more dispersed settings. The majority of interviewees emphasized that for dialogue and collaboration between scientists and engineers to occur in a dispersed setting, a sufficient level of familiarity, trust and social context is desired. This means that management, besides building formal structures (i.e., establishing connections), is concerned with '*facilitating an interface*' between people from different units and different environments. Specifically, management develops experience in making R&D professionals aware of the knowledge base of other units, convincing them of the advantages of knowledge integration, and building trust and a shared identity. Structural embeddedness is seen as a prerequisite for collaboration in multisite projects, together with sufficient technological support for exchange. Nevertheless, relational embeddedness cannot be reached by providing structure alone - it requires the development of a shared identity and trust in order to provide shared understanding. A common way to facilitate a shared identity is to echo this in different ways throughout the organization, for example through spreading messages of shared goals and storytelling. Another way to facilitate stronger ties is physically bringing specialists together. This allows close collaboration, provides the opportunity to build a shared context and a sufficient level of trust to share knowledge. One R&D director in the Netherlands explained how important it is to get familiar with 'the other side', and that a formal introduction is often not sufficient for collaboration between engineers:

> ”What is unknown, is unloved. I myself have had this same feeling. Before my first visit I did not understand many of their actions and thought they were doing things that didn't make sense.” (R&D Director, Company A)

Facilitating an interface in distant relationships requires a combination of engineering and emergent approaches in which structure provides a basis on which relationships can develop. The basic task for management consists of providing organizational structure and allocating responsibilities. Next, what is needed is an environment which helps R&D professionals to contact and get to know each other and each other's specialism where needed. Managers provide a part of this environment, by managing the contacts and projects, and informing managers of other locations on developments and adjustment. The other part, which could be the lion's share of facilitating interface, has a more emergent character in that management can only facilitate the environment. Interviewees explain how the informal structures that were sufficient when R&D was concentrated in a single location, became insufficient when R&D was dispersed across various locations. Much of the misunderstanding between R&D units can be avoided by a higher level of *formalization* of ways of working and responsibilities, which again creates a tension between emergent and engineering approaches.

A majority of the interviewees mention the problem that each unit in a dispersed collaboration supposes its own dominant logic (its belief structures and frames of reference (Bettis and Prahalad, 1995)), to be the starting point of interpretation on how a unit should function and how work should be done. Creating awareness of a unit's own dominant logic and that of other units, and creating a shared identity is found to support shared understanding. The following quote illustrates the influence of dominant logic on the understanding between units:

> “People who are doing one activity, they think that this is the only way to do this, and this is right. And they have been working like that for a number of years. Now, a person of that level of expertise will really have a hard time if another person comes and then says ‘hey, what you are doing is not right in the present scenario’. Sometimes it is very difficult to believe that because we believe that what we do is the only thing that is right. It’s human nature.” (R&D Manager in India, Company C)

4.2. Situated learning

The embedded, situated and emergent nature of R&D work means that management is primarily concerned with providing an adequately flexible environment in which professionals can collaborate, while the organization can benefit from their activities. The findings illustrate that management develops an awareness of the complex and situationally embedded nature of R&D professionals’ activities. When structure and valuable relations are created between units, specialists start value the need for collaboration, and a process of sharing expertise, learning and knowledge creation commences. This process is understood to be embedded in shared practices, which is reflected in the lower part of Figure 2 where emergent approaches play a role, and connections and content are combined in practice. This hands-off approach towards situated learning is how managers tend to cope with the challenges of relational embeddedness and knowledge as practice. One manager recalled:

> “You know, eventually they come back to me with a new concept or design which has features which I can see coming from both platforms. The process they go through before they come to me is one that is incredibly complex. I can’t explain how they ‘generate’ new knowledge, neither can they.” (R&D Director, Company A)

Embeddedness of knowledge in a shared context facilitates common ground between units, while the more locally embedded knowledge is, the more difficult this becomes. For R&D work in particular, where knowledge can be highly tacit and is concerns very specific expertise, knowledge integration can be problematic. A Dutch manager who has been working in India for somw years commented on the nature of R&D work in his organization:

> ”Well, what we have to do is bring specialists together who understand each others’ specialist language. And if you do this, you should keep the lines very short, and sometimes, you should place them physically together. This is not always possible, for example if part of the team is not in India. But if you at least put them together in one team, you see that people are willing to collaborate. So, let me say, you should not let hierarchy get in the way, just let them work together directly.” (Manager, Company C)

Managers show awareness of the social process involved in R&D work, and understand that efforts are required to create a positive climate. These efforts are typical of a laissez-faire kind of approach, or balancing between providing organization and providing enough room for creativity. Managers realize that their role is primarily in facilitating this process.

4.3. Knowledge integration

Knowledge integration concerns the translation of situated knowledge into organizational knowledge. Interviewees mentioned that knowledge is derived from its embedded context by patenting and formalization, but were aware of the tension this creates with the situated learning process. As illustrated above, the embedded nature of R&D knowledge makes it difficult to externalize into organizational knowledge. The following statement is illustrative in this respect:

> "I think the sort of things which are in the formal documents - whether in Bangalore or in The Netherlands - are easily accessible and understandable. But certain things which are in the minds of the people, for that we do not know whether everything is transferred to the other person or whether it is transferred all. Because that is really unrealistic." (Manager in India, company C)

Managers do try to achieve a form of organizational knowledge for purposes such as retention of specialist knowledge when specialists leave the organization and to have more explicit information available in making strategic decisions. Patenting is primarily done in the early stages (research) to protect intellectual property. However, a second role of patenting identified by interviewees is explicating an organization's own knowledge. At later stages in R&D (development), formalization and efficiency can play a role without killing the creative nature of R&D work.

Coping with the tension between a 'laissez faire' approach of learning in practice, and the translation of this new locally embedded knowledge into organizational knowledge, requires a balancing act between specialization and knowledge integration. Where knowledge can be highly tacit and is often embedded in people's experience, knowledge integration can be problematic if specialists do not work together physically.

> "We base our work on what we experience in this field, in our country. If our colleagues overseas do not understand us, this (specific circumstances) is sometimes difficult to be aware of and explain." (Technical specialist, Company B)

4.4. Road mapping

Road mapping describes the process of implementing what is learned into new strategies and structures in the organization. With the input of newly created knowledge and capabilities, management defines a new status quo for the R&D portfolio and determines new opportunities for collaboration and projects. This is clearly an engineering process, with a focus on both 'connections' and 'content', where content is used as input to determine what knowledge resides in the portfolio and how this can be deployed in new connections. In this process, (corporate) management decides upon new courses of action. These decisions are mostly made by program managers, who get information on new opportunities from their own centers of excellence or project teams, and subsequently inform each other. This leads to new road maps for the R&D portfolio.

Where possible, new knowledge and capabilities in the organization are identified and allocated, and serve as input for the process of adjusting short and long term project management. In addition, this process of road mapping uses the new portfolio of knowledge and capabilities to determine opportunities for the organization, which reflects in new organizational configuration. The organizations under study all show different ‘road mapping’ processes, starting from centralized decision making in collaboration with the corporate organization on one side of the spectrum, towards independent road mapping in more autonomous units in local settings on the other. This is reflected in the following quote:

> ”A couple of times a year we arrange the program management team meeting. Program managers and innovation managers of groups who join the program come together, catch up with each other, and discuss the program concerning content. An example: Where are we going with our lighting division? What are important challenges? This way, we all get informed on what challenges are present. At the same time, I see these meetings as an opportunity to understand this is important in the US, that is important in Shanghai, and so forth.” (R&D Director, company B)

4.5. Interrelated processes: A learning cycle

Our analysis suggests that managing the R&D portfolio is affected by the interrelatedness of the challenges and processes. We found that these different processes form an iterative learning cycle, both complementing and conflicting with each other. For example, while the challenge to see knowledge as practice enhances the opportunity for practice-based knowledge creation by its ‘laissez faire’ approach, the ‘hands on’ strategy’ required by the challenge of creating knowledge as capital is likely to negatively affect this process. This shows that the two challenges should be managed in a comparative assessment of one another. Following this line of argument, these combinations can be found in all processes in the model – each process tackles a combination of interrelated challenges.

The findings furthermore identify the development of learning processes over time. Next to their interrelatedness, the identified processes offer the possibility of mutual reinforcement, as they all build on the results of the other processes. For instance, situated learning is improved if the facilitating interface process has helped in establishing structural and relational embeddedness, possibly creating new connections via which practices are shared. This situated learning, in turn, feeds into the knowledge integration process. Next, knowledge integration provides the basis for road mapping, as what the organization knows (and needs to know) strongly determines the future direction for R&D. This direction is an important shaping condition for new connections, on which the facilitating interface process builds.

In time, these processes become more and more routine for management, as they build experience in dealing with knowledge integration issues. If all four challenges are managed through their interrelated processes, the learning cycle should prove effective. Otherwise, one or more of the challenges are not met – for instance, if situated learning does not take place, there is little for knowledge integration to build on. In one of the organizations several interviewees described how difficult the facilitation of an interface between India and The Netherlands had been from the start. During the first phase of a joint R&D project, many problems arose due to miscommunication and lack of mutual understanding. Management reacted upon this issue by structuring and controlling the whole project in all kinds of ways, such as imposing a detailed structure of the process of integration of expertise between units. This approach adversely affected the willingness of researchers and engineers to participate, and the project failed. From this and a few other 'trial and errors' in the organization, management gained insight in how to approach integration between units. Over time, experience and capabilities had been developed, and projects started to yield positive results.

4.6. Case illustration: Management challenges at PrintCo R&D

In this section we illustrate the dynamics in the R&D management learning cycle with a brief description of our findings concerning a multisite R&D collaboration at PrintCo, a multinational company specialized in display graphics systems. Headquartered in the Netherlands and employing about 800 R&D workers, the company acquired a small subsidiary in Canada specialized in state of the art of printing technology, reflected in the "Jupiter" line of printers. The Canadian unit consisted of about 40 engineers. All expert knowledge on the Jupiter technology, including knowledge on mechanics, electronics, software and system integration, resided in the subsidiary in Canada.

A few years after the acquisition, PrintCo decided to raise the level of knowledge integration between Canada and the Netherlands in order to gain synergy for the organization as a whole. Initiated in the Netherlands, project "Pluto" was started, which would be the first large joint project involving both Canada and the Netherlands. The major plan was to use Canada's Jupiter printing technology on top of an automated print table designed in the Dutch unit. The table had been developed in the past years in the Netherlands, but resource scarcity in the Dutch unit made it impossible to finish the project in time with enough expertise. So, as part of the *road mapping* process, the plan was to transfer the table to Canada, and finish the project there.

Project Pluto was communicated as a shared project between the Netherlands and Canada. To assess compatibility of the technology, a number of mutual visits were made by management and lead engineers, and the Canadian unit started to theoretically combine technologies of both units. Here the two groups encountered their first "*interfacing*" hurdles. For example, both units used a different 3D CAD design system, so they could only see versions of the design made by the other unit, but not adjust or fully look into the design. Furthermore, the Canadian unit did not have access to the Dutch headquarters' intranet, which complicated finding the right people and knowledge in the organization. In order to mobilize the situated knowledge from both units in an emergent way, a "wiki" was set up by the engineers to create some kind of shared platform..

In the first few months, several attempts were made to create facilitate the interface between both units, through visits and conference calls. The engineers on the work floor, despite many cultural differences, did value each other as knowledgeable engineers and 'nice guys'. Some strong relations developed, and engineers from different units started working more closely together and sharing their expertise. Afer some time, however, the units found they lacked sufficient common ground to fully understand each other's view on the project and technical requirements. From the point of view of many Dutch respondents, the Canadians did not accept the project from the start. A reason for this (brought up by Canadian and Dutch respondents) could be that this was the first project that was "planted" in Canada by the Dutch, and the Canadians did not feel a great level of ownership for the project. Another (related) reason brought up by both groups was a different approach towards project initiation. Both groups were accustomed to a balancing process between what the strategic planning department demands from the R&D department on the one hand, and what the R&D department can offer on the other. So when the Pluto project was introduced to them, the Canadians started by assessing the project's feasibility, and kept bringing up technical shortcomings of the project. The Dutch perceived this behavior as somewhat resistant towards the collaboration, while for the Canadians this was their usual way of working. Between large parts of both groups resistance to the collaboration remained. So despite considerable efforts in terms of facilitating interface, it turned out to be very difficult to create enough common ground between Canada and the Netherlands to let situated learning processes emerge that involved both units.

Nevertheless, the two units did try to work together, and the atmosphere was often collaborative on an operational level, where professionals did try to get situated learning off the ground. An important barrier to this process, however, was the Canadians' lack of ownership of the project, compared to how they felt about prior projects. For example, many Canadians expressed doubts whether the project would ultimately lead to a new product, further decreasing their willingness to actively participate in it. After some months of coping with this situation, PrintCo was also confronted with some major downsizing decisions. Subsequently, after 1.5 years of collaboration, management decided to discontinue the project. Respondents gave many different reasons for this cancellation, but the general feeling was that 'it was just not working'.

Because the project was cancelled before sufficient levels of common ground and situated learning were reached, management was not in the position to actually realize necessary knowledge integration processes to "extract" knowledge from practice, and to generate a form of organizational knowledge that the rest of the company could benefit from. This in turn interfered with management's road mapping processes to develop new projects between Canada and the Netherlands and other locations.

The company learned a lot from the cancelled project. Management as well as engineers emphasized the importance of first realizing 'connections' in terms of structure and trust on the work floor and with managerial levels, before the actual R&D work ('content') could take place. Respondents also noted that managing dispersed R&D projects is from the start a process of unlearning one's own routines, and learning routines that work best for both parties. In terms of the R&D management cycle, the situated learning part (where the actual knowledge is created and shared) did not take off. The analysis also indicates that the 'connections' in terms of both structural and relational embeddedness were not yet sufficiently established to provide a common ground for collaboration. From a structural embeddedness perspective (deliberate approach), information technology tools weren't sufficiently adapted to facilitate infrastructure. From a relational embeddedness perspective (emergent approach), there was a lack of relational capital (acceptation/trust) to create enough common ground to learn from each other and exploit each other's knowledge.

5. DISCUSSION

This paper provides insight into the challenges created by the increasing dispersedness of R&D activities, as well as into the processes through which to cope with these challenges. Based on challenges and processes, we propose the global R&D management learning cycle, which builds on the notion that challenges and processes are strongly interrelated, and have the potential to both conflict with each other and mutually reinforce one another. Although the cyclic character of this model implies that there is no clear beginning or end, our findings indicate that, after the strategic planning process of road mapping, management interventions in the dispersed R&D process do tend to focus on establishing connections and relationships, i.e. facilitating interface. Management generally shows an awareness of the fact that the actual knowledge creation and sharing processes between R&D people are not to be directly interfered with – they primarily see management's role in creating the conditions for these processes by putting the right people together. The processes that take place between these people (situated learning) are not the subject of management interventions, but the knowledge that results from these processes to a certain extent is: managers do see a role for themselves in the process of knowledge integration, but they show an awareness that this requires a delicate balance between the emergent character of the knowledge processes, and the engineering interest of integrating the outcomes of these processes. The strategic process of road mapping is a typical management process, in which the organizational knowledge base is used to decide new directions for R&D. So in general, the core knowledge creation process of situated learning is one in which management tends not to interfere, but through facilitating interface, knowledge integration and road mapping, it does aim to create the optimal conditions for this process.

With this, our study has two main contributions. First, where previous research has mainly approached the tension between specialization and integration from a purely managerial perspective, our findings show that the emergent nature of knowledge processes should also be taken into account. Specifically, management processes entail both top-down and bottom-up approaches, and are highly interrelated. Second, we observe an interrelatedness of these processes across space and time, emphasizing the dynamic character of managing dispersed R&D. We will further outline these contributions in the following paragraphs.

5.1. Theoretical implications

While most theory on specialization and integration focuses on the balancing act between the two strategies on a managerial level, this study describes the tension between specialization and integration from a more practice based perspective, involving micro level processes in the actual R&D work. Our findings provide detailed insight in the origins of challenges faced on a managerial level, and suggest how these challenges should be coped with by describing coping processes in their original context. Crucially, we find that management's role is primarily in creating conditions for the process of situated learning. Situated learning itself is very much emergent, and any deliberate interventions are not directly aimed at this process, but at creating conditions for this process to take place: facilitating interface between professionals, and integrating the knowledge resulting from this process to an organizational level, thus institutionalizing and validating the outcomes of the process. This closely relates to work on 'semistructures', which implies that organizations partly have structures that can be determined in advance and have clear intervals and goals, and partly entail an unstructured part in order to maintain freedom which is crucial for knowledge creation and adjustment in the R&D work itself (Brown & Eisenhardt, 1997).

Furthermore, our findings point towards the importance of both space and time in balancing specialization and integration in managing dispersed R&D. As the challenges identified in this study are closely related, addressing one challenge always involves the context of the other challenges to understand specific choices that have to be made. Within dispersed R&D settings, where parts of the cycle are geographically dispersed over multiple units, the additional challenge is to keep up with this interrelatedness across barriers of space: the fact that units are placed at different location complicates managing processes in a concerted way. If parts of the cycle are performed without taking the context of the other processes into consideration, the cycle may fail since processes do not reinforce each other. For example, if the process of situated learning does not have a clear view on the road mapping process, this may cause a lack of focus in a project. Vice versa, if the road mapping process does not take into account the multiple challenges of creating relational embeddedness in multisite projects, it may cause projects to fail on the basis of inconsistencies between R&D sites. We clearly saw this happen in the PrintCo case, where the organization did not succeed in facilitating an interface between geographically dispersed professionals, as a consequence of which the road mapping process (which took place in The Netherlands) was never translated into situated learning (in which the participation of the Canadian unit was essential).

Secondly, the processes described between the challenges not only illustrate this interrelatedness in terms of space, but also how this cycle evolves in time. Taking the model through different projects reveals development of the challenges, which in the beginning may be a process of trial and error itself, but in the path of time and experience will become more familiar and routine based. This finding reflects other work on innovation work. Brown and Eisenhardt (1997) for example, describe how organizations became successful in managing their portfolio, by creating 'links in time', developing their understanding of innovation processes and becoming more pro-active in coping with challenges as opposed to reacting and following upon what was faced. Straudenmayer et al. (2002) describe from an opposite point of view how necessary the experience of time is to understand organizational capabilities and develop routines for them. They illustrate how temporal shifts, or 'changes in rhythm', are fundamental to triggering, coordinating, and reallocating in organizational development, and how this in turn nourishes the ability to create routines that detect and act upon challenges in the field. Likewise, Feldman and Pentland (2003) illustrate routines as enablers of ongoing performance, developing capabilities for an organization to become more adaptable or flexible because of prior experience. Grimpe and Kaiser (2010) argue that 'experience might even substitute for the tacit knowledge component that is difficult to transfer between units' (Grimpe and Kaiser 2010: 1491). In this respect, the learning cycle in the context of global R&D settings evolves from a process of hitches and trial and error, into a process in which familiarity and routinization for managers as well as serve as input for coping with challenges.

5.2. Practical implications

For practice, the main implication from this study lies in the dual role management can have in creating 'connections' before managing 'content'. This role has both deliberate and emergent aspects, but in practice the emergent aspects are often overlooked. The reason for this is that many of the emergent processes that feed relational embeddedness occur naturally when projects are centrally organized, but need more facilitation when projects are dispersed. In dispersed project settings, the natural tendency for management is emphasize deliberate interventions in order to compensate for the complications that result from dispersing R&D - for example by allocating tasks and responsibilities in a top-down fashion. The downside of this approach is often that this creates more distance between managerial levels, and distance between in this case, different locations. Even more facilitation is needed to create an interface in which collaboration can take place. Managers facing the challenge of dispersed R&D settings should be aware of this tension, and strive to find a balance between deliberate interventions and a more 'hands-off' approach.

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Appendix 1. Challenges and processes of the R&D management learning cycle

Concepts	Processes	Definition	Exemplary quotes
Structural embeddedness		The extent to which specialists of different units are connected to each other and know who knows what	'One thing we did, we deliberately chose to structure different hierarchical lines forth and back between units.'
Relational embeddedness		The extent to which the collaboration is characterized by strong social ties, as a mechanism for gaining fine-grained information	'…and you should have some trust, sharing your documents, others will look into it.' 'Especially the us-them thoughts we try to nip in the bud.'
Embeddedness in practice		The extent to which knowledge and knowledge creation is integrated in the practice of the R&D work, and difficult to extract from practice	'Now we work locally focused, project roadmap driven, so that means, all these capabilities have to build up very dedicated, it is not very broad.'
Organizational knowledge		Knowledge which is made visible for (management of) other parts of the organization besides from where it is created.	'From a business point of view if we see some of the technologies we don't want to be copied quickly, those kind of technologies we are thinking are in a very crucial for (company B) whole business. Than we are very careful. Sometimes they even don't want to allocate the core technology part in China. They want to avoid that.'
	Facilitating interface	Creating an environment for sufficient relational embeddedness to collaborate in dispersed settings	'Well, maybe not even that you actually have to meet face to face with everybody separately, I think it is important that you've been there at their work place for more than one day.'
	Situated learning	Learning and creating knowledge and capabilities which cannot occur apart from practice	'At the headquarters we have decades of experience and learning in our technologies. In India we have enough new scientists, but no experience. This excellence is difficult to transfer.' 'What we know here is a collection of years and years of work.'

			‘Local policies influence how and what we communicate around here. ’
	Knowledge integration	The process of making new knowledge visible to other parts of the organization	‘We use our market knowledge to develop many concepts, which can be difficult to understand for nonlocals.’
	Road mapping	Determining and acting upon new opportunities in the R&D portfolio.	‘Everything is in global direction of projects. We know where there is a need, we know where technology is developed, and that we match together.’