Doctoral Thesis

Striving for Product Development Excellence - Lessons Learned from the Implementation of Lean Management

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STRIVING FOR PRODUCT DEVELOPMENT EXCELLENCE – LESSONS LEARNED FROM THE IMPLEMENTATION OF LEAN MANAGEMENT

A thesis submitted to attain the degree of

DOCTOR OF SCIENCES of ETH ZURICH

(Dr. sc. ETH Zurich)

presented by

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2014
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Although in the end only a single name appears on the cover, writing a dissertation takes more than the effort and passion of an individual. It takes the support and companionship of family and friends to motivate in times of doubt and to share the joy in times of success.

I thank Prof. Stefano Brusoni for his advice, support and gentle pressure to conduct rigorous research, to eventually finalize my dissertation and to achieve the goals we set. I would also like to thank him for encouraging me to participate in numerous conferences and workshops at which I had the possibility to meet and learn from the very best scholars in our field. For a young researcher that was not only highly motivating, but sometimes also slightly daunting.

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Last but not least, I am deeply grateful to my parents, Andrea and Andreas, who made all this possible by supporting and encouraging me along my way.
SUMMARY

Firms face ever increasing challenges in relation to new product development (NPD). Product life cycles are becoming shorter, technologies are becoming increasingly complex, and customer requirements are becoming more demanding. As a consequence, firms need to streamline their development processes and involve specialists from within and outside the organization. To address these challenges, firms are experimenting with process management concepts such as lean management. However, the introduction of process improvement techniques to NPD can be difficult, since they often increase efficiency but at the expense of creativity. Hence, few firms manage to fully transform their NPD organization into a lean product development (LPD) organization.

This dissertation provides new insights into the multi-faceted process related to the adoption of management innovations. It focuses particularly on the learning processes underpinning the adoption of new managerial practices that result in transformations of existing capabilities. The thesis identifies two basic learning processes. The first, learning about tools, is related to the introduction of new managerial practices that depend on two distinct types of knowledge, namely improvement knowledge and process knowledge. In the context of this dissertation, improvement knowledge corresponds to knowledge about lean management and process knowledge relates to the idiosyncrasies of the NPD process. The second learning process, learning about the system, comprises those processes that lead to the integration of different lean management tools into a coherent LPD system. This integration process is driven by bottom-up learning which is triggered by internal feedback on the performance of the NPD process. Thus, it is suggested that existing top-down learning models of capability development could be complemented by a bottom-up learning process.

By providing insights into the nature and functioning of lean management tools in NPD, this dissertation provides advice that should be valuable to practitioners and could serve as a template for the introduction of successful LPD systems.
ZUSAMMENFASSUNG


Diese Dissertation gewährt zudem detaillierte Einblicke in die Funktionsweise von Lean Management Techniken in der Produktentwicklung und kann daher von Führungskräften, die vor der Einführung ähnlicher Managementkonzepte stehen, als Vorlage eingesetzt werden.
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LIST OF ABBREVIATIONS

e.g. for example, for instance (Latin: example grandi)
et al. and other people (Latin: et alii/alia)
etc. et cetera
i.e. that is, in other words (Latin: id et)
LPD Lean Product Development
NPD New Product Development
R&D Research and Development
“NOTHING ENDURES BUT CHANGE.”
Heraclitus, Greek philosopher (535BC - 475BC)

1 INTRODUCTION

Firms introduce new managerial practices to increase productivity, improve quality, and maintain competitiveness (Mol & Birkinshaw, 2009). This type of innovative activity is generally known as management innovation (Damanpour & Aravind, 2012), which Birkinshaw, Hamel and Mol (2008:825) define as “the invention and implementation of a management practice, process, structure or technique that is new to the state of the art and is intended to further organizational goals”. In addition to the original development of new managerial practices, the concept of management innovation also includes the successful implementation of managerial practices that are new to an adopting organization (Damanpour & Schneider, 2006; Mol & Birkinshaw, 2009). The list of management ideas that organizations have experimented with is long (for an overview: Birkinshaw et al., 2008) and includes well-known quality improvement programs such as total quality management, six sigma, and lean management.

However, introducing new managerial practices can be difficult and not all firms are equally successful. For example, General Electric encountered more difficulties in the introduction of Six Sigma than did Motorola (Ansari, Fiss, & Zajac, 2010). Klein and Sorra (1996) argue that these difficulties are attributable either to the innovation itself, or to the implementation process. Given the success of Six Sigma in many cases, what distinguishes successful from less successful adoptions would seem to be the implementation process. Researchers have identified different phases in this process (Damanpour & Aravind, 2012). For instance, Hage and Aiken (1970) distinguish between evaluation, initiation, implementation, and routinization. These phases apply to different types of innovations. What varies, however, is who initiates the implementation process. While technical innovations are often initiated at the operating core and follow a bottom-up implementation process, management innovation typically is launched at top management level and follows a top-down process (Daft, 1978). Senior management thus plays a decisive role in the implementation of a new management concept involving technical, cultural, and political challenges (Ansari et al., 2010; Canato, Ravasi, & Phillips, 2013). Despite these
omnipresent challenges, the implementation of management innovation has received much less attention than the implementation of technological innovation (Mol & Birkinshaw, 2009), and the literature on this area is in its early stage (Damanpour & Aravind, 2012). This dissertation is a modest attempt to shine some light on the implementation of managerial practices and enhance understanding of the adoption process.

This doctoral research studies the implementation of managerial practices in the context of research and development (R&D). In particular, I look at five companies that introduced lean management tools and techniques in their new product development (NPD) in order to create a lean product development (LPD) organization. In so doing, these companies transformed their existing NPD capabilities into LPD capabilities (Figure 1).

Winter (2003:991) defines organizational capability as follows: “An organizational capability is a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization’s management a set of decision options for producing significant outputs of a particular type”. Consequently, transformation of an organizational capability involves acquisition, modification, and rejection of routines (Lavie, 2006). Thus, the concept of capability transformation provides an excellent framework to study management innovation since new managerial practices build on, modify, and complement existing routines rather than substituting for them. My interest is especially in the learning processes that facilitate the acquisition and modification of routines to enable the transformation of organizational capabilities and is guided by the following research question:

| What are the learning mechanisms that enable the transformation of organizational capabilities? |

Figure 1: General framework

Winter (2003:991) defines organizational capability as follows: “An organizational capability is a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization’s management a set of decision options for producing significant outputs of a particular type”. Consequently, transformation of an organizational capability involves acquisition, modification, and rejection of routines (Lavie, 2006). Thus, the concept of capability transformation provides an excellent framework to study management innovation since new managerial practices build on, modify, and complement existing routines rather than substituting for them. My interest is especially in the learning processes that facilitate the acquisition and modification of routines to enable the transformation of organizational capabilities and is guided by the following research question:

| What are the learning mechanisms that enable the transformation of organizational capabilities? |
This study of the transformation of organizational capabilities makes several contributions to both theory and practice. I identify two broad learning processes, namely *learning about tools* and *learning about the system*. The first learning process includes identification and acquisition of relevant knowledge. The key finding here is that the successful introduction of new tools depends on two distinct types of knowledge, namely improvement knowledge which is knowledge about how to improve business processes, and process knowledge which is knowledge about how to develop products. The latter learning process includes the processes that lead to the integration of different lean management tools within a coherent LPD system. I show that bottom-up learning which is driven by internal performance feedback, is an important driver of capability transformation. Thus, I suggest that existing top-down learning models should be complemented by a bottom-up learning process. By providing insights into the nature and functioning of lean management tools in NPD, my examples could serve as templates for managers keen to introduce similar process monitoring and improvement systems.

Chapter 2 briefly reviews the literature on organizational learning and organizational capabilities. The empirical context is introduced in Chapter 3 and I describe the research design in Chapter 4. Chapter 5 summarizes the six papers that form the body of this cumulative dissertation. I identify the overarching contributions of my research and conclude by discussing some limitations of this research and suggesting avenues for future research.
“STANDING ON THE SHOULDERS OF GIANTS.”

among others Sir Isaac Newton (1642AD - 1727AD)

2 THEORETICAL BACKGROUND

2.1 Organizational Learning

Organizations learn and adapt in order to ensure their long-term survival in a changing environment (Fiol & Lyles, 1985; Levinthal & March, 1993). Learning allows organizations to develop unique skills and competencies that have the potential to create sustained competitive advantage (Pisano, 2000). These learning processes are routine-based, path-dependent, and target-oriented (Levitt & March, 1988). The key question is how organizations learn from past experiences, or more precisely, how individuals learn from past experience since the locus of organizational learning is the individual (Grant, 1996). However, organizational learning is more than the sum of the learning of all the organization’s individuals/employees; the organization enables supra-individual learning through the development and maintenance of learning systems (Fiol & Lyles, 1985). These learning systems are built on the creation, acquisition, and combination of knowledge and knowledge transfer processes (Argote, 2013; Garvin, Edmondson, & Gino, 2008). Therefore, understanding the process of organizational learning is a necessary prerequisite to understanding the creation and evolution of routines which, in turn, are the basic components of organizational capabilities (Helfat & Peteraf, 2003; Nelson & Winter, 1982). Routines bridge between organizational learning and organizational capabilities. Yet, we know little about the link between organizational learning and the evolution of capabilities (Argote, 2011; Easterby-Smith, Lyles, & Tsang, 2008). To examine this relationship, I build on the literature on the creation and transfer of knowledge (Nonaka, 1994; Szulanski, 1996), and learning from direct versus indirect experience (Argote & Miron-Spektor, 2011; Levinthal & March, 1993).

2.1.1 Knowledge creation and transfer

Organizational knowledge creation is defined as “the process of making available and amplifying knowledge created by individuals as well as crystallizing and connecting it to an organization’s knowledge system” (Nonaka & Von Krogh, 2009:635). Knowledge
creation is a topic of great interest to both scholars and practitioners in several fields such as organizational learning, innovation, and the knowledge-based view of the firm (Tsoukas, 2009). Creating knowledge is a highly interactive process involving individuals on the one hand (Brown & Duguid, 2001; Nonaka, 1994), and different types of knowledge on the other (Davenport, 1993; Grant, 1996). The most influential model of knowledge creation was developed by Nonaka and colleagues (Nonaka, 1994; Nonaka & Takeuchi, 1995). Their socialization-externalization-combination-internalization (SECI) model describes the creation of knowledge as a processes in which tacit and explicit types of knowledge interact (Nonaka, Toyama, & Konno, 2000). This dissertation builds on various findings from the knowledge creation literature. First, it is important to understand that knowledge exists in tacit and explicit forms (Polanyi, 1966; Ryle, 1949) which has direct implications for its availability, articulation, and transfer (Zander & Kogut, 1995). Second, different individuals contribute different types of knowledge to the process of new knowledge creation (Grant, 1996; Nonaka, 1994). Therefore, organizations need to establish processes that allow individuals to directly or indirectly share their knowledge, and learn from the experience of others (Argote, 2013; Argote & Miron-Spektor, 2011). Knowledge transfer occurs when the knowledge embedded in one organization, group, or individual, affects the knowledge of another organization, group, or individual (Argote & Ingram, 2000; Levitt & March, 1988). However, the transfer of knowledge across boundaries is challenging and is influenced by a number of factors (Carlile, 2002, 2004) related to the transfer process, the source and recipient context, and the characteristics of the knowledge being transferred (Argote, 2013; Szulanski, 1996).

2.1.2 Learning form direct and indirect experience

Organizational learning can be viewed as a change to the organization’s knowledge as the result of acquiring experience (Argote & Miron-Spektor, 2011). This experience can be distinguished along multiple dimensions including organizational, content, spatial and temporal (Argote & Todorova, 2007). What is important is whether organizations learn from their own experience or from the experiences of others (Huber, 1991; Levitt & March, 1988). While learning processes such as trial-and-error, experiential learning, and improvisational learning are related to learning from direct experience (Bingham & Davis, 2012), vicarious learning refers to learning from indirect experience (Argote, 2013). Learning from indirect experience is common in organizations, as they attempt to learn about the successful strategies, administrative practices, and technologies of other
organizations (Huber, 1991; Levitt & March, 1988). Organization frequently try to copy higher-status organizations which act as role models (Argote, Beckman, & Epple, 1990; Jensen & Szulanski, 2007). For example, organizations around the world learned about lean management from Toyota (Morgan & Liker, 2006; Womack, Jones, & Roos, 1990). Without discussing the process of learning from experience in more detail, it can be argued that the more distant the experience in terms of context, space, and time, the more difficult it is to learn from it and the greater the risk of drawing inappropriate inferences from such experience (Argote & Miron-Spektor, 2011; Tripsas & Gavetti, 2000). This makes the adoption of routines and capabilities a major challenge.

2.2 Organizational Capabilities

Organizational capabilities are “a major source for the generation and development of sustainable competitive advantage” (Schreyögg & Kliesch-Eberl, 2007:913). I build on the evolutionary theory of the firm (Nelson & Winter, 1982) which suggests that organizational capabilities are embedded in an organization’s routines (Dosi, Nelson, & Winter, 2000; Gavetti, 2005). Thus, different configurations of routines generate different types of capabilities (Lavie, 2006; Winter, 2000). In order to understand how organizations maintain competitive advantage, it is necessary to know how they create and adapt their capabilities, that is, how they acquire, modify, and configure the corresponding routines.

Organizational routines have been defined as “repetitive, recognizable patterns of interdependent actions, carried out by multiple actors” (Feldman & Pentland, 2003:95). It is generally accepted that routines and capabilities are the product of path-dependent organizational learning (Argote, 2013; Salvato, 2009) and that implicit learning-by-doing as well as more deliberate learning processes contribute to their development (Ethiraj, Kale, Krishnan, & Singh, 2005; Zollo & Winter, 2002). Following Nonaka’s (1994) model of knowledge creation, and Campbell’s (1969) classical variation, selection, and retention paradigm, (Zollo & Winter, 2002) suggest a four stage learning model to explain the development of organizational capabilities. This learning process is driven by both external stimuli and internal feedback (Zahra, Sapienza, & Davidsson, 2006; Zollo & Winter, 2002). Ambrosini and Bowman (2009) elaborate on this, arguing that managerial perception of the need for change is triggered by external and internal stimuli such as performance gaps or personal motivation. However, perception of the need for change is not sufficient. (Penrose, 1959) argues that change to existing capabilities depends also on
the managerial capacity to implement the necessary changes. This implies that organizations need monitoring systems that allow their managers to sense the signals, that indicate a need for adjustment to existing capabilities (Schreyögg & Kliesch-Eberl, 2007), and that they need dedicated routines or capabilities to implement the necessary changes (Helfat et al., 2007).

Lavie (2006) distinguishes between capability substitution, transformation, and evolution which all lie on a continuum. Given that organizations typically have a portfolio of capabilities, capability substitution refers to the acquisition, rejection, or retention of an entire capability. At the other extreme, organizations can modify single routines to adjust or improve a given capability. In between these extremes are different degrees of capability transformation which implies that the configuration of routines changes as some are modified or discarded, and some new ones are acquired.

Capabilities researchers distinguish among different types of capabilities. The most basic distinction is between operating routines and dynamic capabilities (Helfat & Peteraf, 2003; Zollo & Winter, 2002). While operating routines ensure the organization’s basic functioning (Nelson & Winter, 1982), dynamic capabilities act upon these operating routines, continually adapting and reconfiguring them, so that they match changing internal and external conditions (Helfat et al., 2007). In their seminal paper, Teece et al. (1997:516) defined “dynamic capabilities as the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments”. Incorporating the routines perspective, Zollo and Winter (2002:340) refined Teece et al.’s definition and describing dynamic capability as “a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness”. Dynamic capabilities are described as crucial for the firm, because without them, a given set of operating routines does not provide the organization with sustained competitive advantage (Collis, 1994). An interesting aspect of the categorization of capabilities is that these definitions indicate a hierarchical relationship between different types of capabilities. Winter (2003) distinguishes between zero-level capabilities and several levels of higher-order capabilities that modify the next (lower) level capabilities. First-order capabilities act upon zero-level capabilities, second-order capabilities upon first-order capabilities, and so on ‘ad infinitum’ (Collis, 1994). The distinction between different types and levels of hierarchies is important because organizations need to invest in these higher-level improvement
capabilities to ensure their long-term survival (Eisenhardt & Martin, 2000; Teece et al., 1997). Since value is not produced by these higher-order learning capabilities on their own, but through the operating routines that they act upon (Helfat et al., 2007), the development of dynamic capabilities can seem a costly and sometimes unrewarding task in the short term.

This short overview of the literature shows how learning processes contribute to the development and transformation of organizational capabilities (Zollo & Winter, 2002), which are a major source of competitive advantage (Barney, 1991; Schreyögg & Kliesch-Eberl, 2007). However, we know very little about how new organizational capabilities emerge and evolve over time (Ethiraj et al., 2005; Felin, Foss, Heimeriks, & Madsen, 2012). In Chapter 3, I introduce the empirical context for the study of the transformation of organizational capabilities.
“A DESIGNER KNOWS HE HAS ACHIEVED PERFECTION NOT WHEN THERE IS NOTHING LEFT TO ADD, BUT WHEN THERE IS NOTHING LEFT TO TAKE AWAY.”

Antoine de Saint-Exupéry (1900AD – 1944AD)

3 EMPIRICAL BACKGROUND

New product development (NPD) is a key source of competitive advantage (Brown & Eisenhardt, 1995; Leonard-Barton, 1992) but the development of products is a complex process that is difficult to manage (Goffin & Koners, 2011). Moreover, the complexity of NPD is increasing steadily. First, technological progress renders existing competencies obsolete and requires the development of new ones (Leonard-Barton, 1992), and firms that are not able to adapt to new technological paradigms will fall behind (Christensen & Bower, 1996). Second, technological developments lead to greater specialization of both individuals and organizations. This requires firms to integrate specialized knowledge from various sources within and outside organizational boundaries (Brusoni, Prencipe, & Pavitt, 2001; Carlile & Rebentisch, 2003), which is resulting in heterogeneous, multi-disciplinary and often dispersed NPD teams (Boutellier, Gassmann, Macho, & Roux, 1998). Third, organizations attempt to open up their NPD processes in order to benefit from the knowledge of their customers and suppliers (Chesbrough, 2004; Sieg, Wallin, & Von Krogh, 2010). Finally, product life cycles are become ever shorter and reduce the lead time for getting new products to market (Edmondson & Nembhard, 2009). Taken together, these developments further complicate the management of NPD. This forces firms to proactively manage their NPD processes by continuously reviewing, and if necessary, adjusting them. To achieve this they have started to experiment with different process management concepts such as lean management.

Lean management originated in the world-famous Toyota Production System (Womack et al., 1990) and has been deployed successfully in numerous firms to streamline manufacturing activities (Rother, 2010). Hall and Johnson (2009:60), for example, state that “thousands of manufacturing companies have achieved tremendous improvements in quality and efficiency by copying the Toyota Production System”. Inspired by the success in manufacturing, companies have started to apply lean management tools and techniques in other functional domains, for example NPD (Anand & Kodali, 2008; Karlsson &
Åhlström, 1996). However, lean manufacturing tools and techniques are not directly applicable in an NPD context, because product development differs from manufacturing along multiple contextual dimensions such as knowledge intensity, levels of uncertainty, and project duration (Reinertsen & Shaeffer, 2005; Thomke & Reinertsen, 2012). Therefore, a value stream mapping the shop floor level will differ from a value stream mapping of the R&D organization because the underlying work processes, and the types of waste that need to be identified, are different (Anand & Kodali, 2008; Rother & Shook, 2003). A number of companies, for example Scania (Ward, Shook, & Sobek, 2007) and Harley Davidson (Oosterwal, 2010), have successfully introduced lean management principles to their NPD. However, many more have failed in the attempt and have not been able to benefit from their investment in lean management.

In the following chapter I describe the research design chosen to examine the introduction of lean management tools and techniques to NPD that has resulted in the transformation of NPD capabilities to LPD capabilities.
“THERE ARE NO FACTS, ONLY INTERPRETATIONS.”

Friedrich Nietzsche (1844AD - 1900AD)

4 RESEARCH DESIGN

This dissertation aims to provide new insights into the learning processes that drive the transformation of organizational capabilities about whose origin and evolution we know very little (Ethiraj et al., 2005). For such an investigation, cases studies are particularly well-suited to produce novel, empirically valid, and testable theory (Eisenhardt, 1989). I chose a multiple case study design to produce the detailed evidence required to examine the learning processes that facilitate the transformation of capabilities (Eisenhardt & Graebner, 2007; Yin, 2009). I conducted two studies: a multiple case study involving four firms, and an organizational ethnography with a fifth firm. According to (Van Maanen, 2011), ethnography is a social practice that involves the study and representation of culture. Ethnographers use the term culture to refer to “the meanings and practices produced, sustained, and altered through interaction” (Van Maanen, 2011:221). Thus, the goal of an organizational ethnographer is to provide a localized understanding of ‘how things work’ in an organization, from different vantage points. I used several data collection methods including interviews, participant observation, and focus groups, in order to develop an in-depth understanding of the introduction and application of lean management in new product development (NPD) and the transformation of organizational capabilities (Spradley, 1979; Van Maanen, 2011).

4.1 Research Setting

The findings in this dissertation are based on analysis of five firms (Table 1). The first study, which I describe as the ‘Process Management Study’, was part of a larger collaborative research project (LEAP) on lean product development (LPD). In the course of this project, I studied four companies (A, B, C, D) whose situations differed and whose reasons for introducing lean management also differed. Company A was in a difficult economic situation and needed to increase R&D productivity. Company B was in a growth phase and needed productivity gains to manage all of its pending projects. Company C was primarily interested in reducing product life cycle time to keep abreast of decreasing
innovation cycles. Company D had a strong process management organization and was looking for new inputs to extent its process management activities. This heterogeneous sample was well suited to studying a variety of issues related to phenomenon of interest. At the end of 2011, Company E joined the LEAP project informally, and began to participate in project meetings. It transpired that Company E had a strong incentive to experiment with lean management and to implement the corresponding tools and techniques in its R&D. The company had been acquired by a larger corporation which required it to become lean in all organizational domains. Hence, Company E’s R&D management team was receiving a lot of support from the top management, which allowed it to invest considerable time and resources into lean transformation. This made Company E an interesting case, and I set up an organizational ethnography to examine its lean transformation in more detail. I refer to this study as the ‘Lean Transformation Study’.

Table 1: Overview case companies

<table>
<thead>
<tr>
<th>Industry</th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
<th>Company E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Automotive (1&lt;sup&gt;st&lt;/sup&gt; tier)</td>
<td>Automotive (1&lt;sup&gt;st&lt;/sup&gt; tier)</td>
<td>Machine Tooling</td>
<td>Automotive (1&lt;sup&gt;st&lt;/sup&gt; tier)</td>
<td>Automation</td>
</tr>
<tr>
<td>Main products</td>
<td>Cooling and air conditioning</td>
<td>Door and window systems</td>
<td>Laser and water jet cutting</td>
<td>Steering systems</td>
<td>Industrial Networking Solutions</td>
</tr>
<tr>
<td>Headcount 2011/12</td>
<td>17500</td>
<td>21000</td>
<td>1500</td>
<td>5300</td>
<td>250&lt;sup&gt;1&lt;/sup&gt; (7000)&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Headquarter</td>
<td>Germany</td>
<td>Germany</td>
<td>Switzerland</td>
<td>Liechtenstein</td>
<td>Germany&lt;sup&gt;2&lt;/sup&gt; (US)&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

4.2 Data Collection

4.2.1 Process management study

I visited the four case companies in autumn 2010 and spring 2011 in order to conduct a series of interviews (Figure 2). During the first interview sessions held in autumn 2010 I focused on asking about continuous improvement in general (Bartezzagli, Corso, & Verganti, 1997; Nilsson-Witell, Antoni, & Dahlgaard, 2005) since the companies had just started to experiment with lean management tools. In enquired particularly about the nature, frequency, and organization of their continuous improvement activities. These data

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<sup>1</sup> Company E is part of a larger corporation. The values in brackets refer to the overall corporation. In Paper 2, I refer to Company E as AutomationInc and its parent company as CableCo

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from these interviews informed a second, more focused interview round in spring 2011. I examined the existing process management activities in more detail (Benner & Tushman, 2002; Repenning & Sterman, 2001) and asked about the companies' first experiences with lean management.

Both sets of interviews involved representatives at different hierarchical levels and with various functional background; this allowed me to analyze their process management activities from different perspectives. Given the open character of the process management study, I used interview guides with open questions in order not to constrain my interview partners, and to glean more information about process management in all its facets (Rubin & Rubin, 2005; Spradley, 1979). Table 2 provides an overview of the interviews that I conducted during the first round. I audiotaped and transcribed the second round of interviews; the first set used a multiple-investigator approach (Eisenhardt, 1989; Pettigrew, 1990) where I and the second interviewer took notes which we compared directly after the interviews.

Table 2: Overview of the interviews (process management study)

<table>
<thead>
<tr>
<th></th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Management</td>
<td>1+0*</td>
<td>1+0</td>
<td>1+0</td>
<td>1+0</td>
<td>4</td>
</tr>
<tr>
<td>Middle Management</td>
<td>2+1</td>
<td>0+2</td>
<td>1+1</td>
<td>3+3</td>
<td>13</td>
</tr>
<tr>
<td>Team Level</td>
<td>5+0</td>
<td>8+2</td>
<td>6+3</td>
<td>3+1</td>
<td>28</td>
</tr>
<tr>
<td>Process Management*</td>
<td>4+3</td>
<td>2+2</td>
<td>1+1</td>
<td>1+1</td>
<td>15</td>
</tr>
<tr>
<td>Total:</td>
<td>16</td>
<td>17</td>
<td>14</td>
<td>13</td>
<td>60</td>
</tr>
</tbody>
</table>

* interviews 2010 + interviews 2011, ** at different hierarchical levels
In line with best practice recommendations for case study research (Eisenhardt, 1989; Yin, 2009), I included data from additional sources. I attended process management related meetings and reviewed presentations, documentation, and training materials. As part of the LEAP project, a number of focus group discussions, workshops, and presentations involving company representatives, and invited practitioners and academics were organized. During these meetings we discussed different aspects of process management in general, and lean management in particular.

From this process management study, I learned how firms organize their process management activities, the kinds of roles they establish to conduct these activities, and how their investment in these activities varied. The insights from this study are discussed in Paper 1 and Paper 4. These cases also informed the design of the lean transformation study with Company E.

4.2.2 Lean transformation study

As already mentioned, Company E started to participate in LEAP project activities at the end of 2011 when I first met with its R&D Director and Project Management Officer. They were responsible for the company’s NPD process management activities, and consequently for the introduction of lean management. After a workshop held in February 2012 and an on-site visit made in July 2012, we decided to engage in a closer research collaboration, which allowed me to conduct a longitudinal, ethnography-type case study. I visited Company E regularly between November 2012 and April 2013, spending about 45 days in all at the company (Figure 2). After the fieldwork phase, I kept track of the firm’s LPD activities via telephone interviews, workshops, and follow-up visits in November 2013 and September 2014.

The close collaboration with Company E allowed me to gather a wealth of data over an extended period of time. The main data source is interviews. Table 3 presents an overview of my interview partners. I was able to conduct formal interviews with representatives from different functions and hierarchical levels. The interviews with the lean directors in Company E’s parent company were particularly insightful because of their vast experience in introducing lean management in various organizational settings although not NPD. This

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2 Within the scope of the LEAP project, we organized four workshops per year which included representatives from the project partners. We also invited lean management experts from academia (including Durward Sobek - Montana State University, Hugh McManus - MIT, and Seiji Manabe - Yokohama National University) and practice (including Hasse Johansson, former Head of R&D in Scania, and Baback Yazdani, former Head of R&D in Landrover Jaguar).
led to some interesting and difficult discussions. In all of the interviews, I applied ethnographic interview techniques (Spradley, 1979). I mostly used open questions to allow interviewees to speak talk uninterrupted. I was keen for them to highlight events and issues that they saw as key during the development and deployment of lean management tools and techniques. I audiotaped and transcribed all the interviews, and organized them for the subsequent coding using the qualitative data analysis software NVivo. In addition to the interviews, I observed several meetings, presentations, and group discussions (Table 4). I attended as many lean management-related events as possible. I was able to review training material, guidelines, and workshops reports which allowed me to triangulate the data from the interviews and participant observations, in order to increase internal as well as construct validity of my findings (Gibbert, Ruigrok, & Wicki, 2008; Mathison, 1988).

Table 3: Overview of interviews (lean transformation study)

<table>
<thead>
<tr>
<th>Position</th>
<th>Hierarchical level</th>
<th>Number of formal interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Unit Manager</td>
<td>Top Management</td>
<td>1</td>
</tr>
<tr>
<td>Present Director R&amp;D</td>
<td>Top Management</td>
<td>3</td>
</tr>
<tr>
<td>Former Director R&amp;D</td>
<td>Top Management</td>
<td>1</td>
</tr>
<tr>
<td>Present Project Management Officer</td>
<td>Team Level</td>
<td>6</td>
</tr>
<tr>
<td>Former Project Management Officer, Lean Black Belt</td>
<td>Team Level</td>
<td>2</td>
</tr>
<tr>
<td>Lean Director 1</td>
<td>Corporate Function</td>
<td>1</td>
</tr>
<tr>
<td>Lean Director 2</td>
<td>Corporate Function</td>
<td>1</td>
</tr>
<tr>
<td>Project Manager 1</td>
<td>Team Level</td>
<td>1</td>
</tr>
<tr>
<td>Project Manager 2</td>
<td>Team Level</td>
<td>1</td>
</tr>
<tr>
<td>Director Product Management</td>
<td>Top Level</td>
<td>1</td>
</tr>
<tr>
<td>Director Program Management</td>
<td>Top Level</td>
<td>2</td>
</tr>
<tr>
<td>Department Head Documentation, Lean Black Belt</td>
<td>Middle Management</td>
<td>1</td>
</tr>
<tr>
<td>Department Head SW 1</td>
<td>Middle Management</td>
<td>1</td>
</tr>
<tr>
<td>Department Head SW 2</td>
<td>Middle Management</td>
<td>1</td>
</tr>
<tr>
<td>Department Head HW</td>
<td>Middle Management</td>
<td>1</td>
</tr>
</tbody>
</table>

Total: 25
Table 4: Overview of observations (lean transformation study)

<table>
<thead>
<tr>
<th>Event</th>
<th>Frequency</th>
<th>(Average) duration</th>
<th># of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean Daily Management</td>
<td>Weekly</td>
<td>20 minutes</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>(Monday Afternoon)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Project Review</td>
<td>Weekly</td>
<td>20 minutes</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>(Monday Afternoon)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaizen Event</td>
<td>On demand</td>
<td>1 week</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>(in R&amp;D about every two years)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kaizen Sustainment Board</td>
<td>Bi-weekly</td>
<td>5 minutes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>(Monday Afternoon)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-Why Problem Solving Event</td>
<td>On demand</td>
<td>1 hour</td>
<td>1</td>
</tr>
<tr>
<td>5-Why Training Session</td>
<td>On demand</td>
<td>4 hours</td>
<td>1</td>
</tr>
<tr>
<td>Focus group discussions and external workshops with lean experts (LEAP events)</td>
<td>3-4 times a year</td>
<td>1-2 days</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total:</strong> 27</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This organizational ethnography provided in-depth understanding of the organizational learning processes underlying the transformation of organizational capabilities. The evidence from this case study was used to produce Papers 2 and 5.

4.2.3 Complementary projects

Taken together, the five cases highlight a number of additional organizational learning related issues that were not the main focus of the process management or lean transformation study. These findings informed the set-up and conduct of two small, complementary research projects. I do not detail these projects here but since they highlight important socio-technical developments that influence the transformation of capabilities, they are included in my framework. The first project comprised an extensive review of the organizational learning literature and an interview with Prof. Linda Argote, a leading scholar in the field, about the future of organizational learning research. This research provides insights into how recent technological developments influence where and how people work. Organizations need to rethink their communication and collaboration routines which necessitates adaptations to existing capabilities. The second project was a small study on the influence of workspace on cross-disciplinary learning.

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3 This project was conducted jointly with Sunkee Lee (INSEAD). The interview was conducted during the pre-conference program of the Knowledge & Innovation Interest Group at the 2013 Annual Meeting of the Strategic Management Society in Atlanta.
Workspace influences how people communicate and collaborate. It can thus support or inhibit learning in teams and organizations. This is an important aspect; organizations often stress the importance of lean work processes but do not consider the influence of the physical environment in which they unfold. These two projects were the basis for Papers 3 and 6.

### 4.3 Data Analysis

The findings from this dissertation research are based on a highly iterative data analysis process within and across cases, with numerous data coding, data reduction, and data recoding cycles (Miles & Huberman, 1994). Going back and forth between my data and the existing theory (Eisenhardt, 1989), I was able, by applying different theoretical lenses, to analyze the data from different perspectives. More information on the data collection and analysis procedures is provided in the individual papers.

In the next chapter, I provide an overview of the attached papers and summarize their content in order to show to which aspects of the dissertation they relate.

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4 The project was a collaboration with Annina Coradi (ETH Zürich) and included analysis and conceptualization of a Transdisciplinary Research Lab (TdLab) in the Environmental Science Department (D-USYS) of ETH Zürich.
5 SUMMARY OF THE PAPERS

The findings from my research are the basis of six papers, grouped according to their content and main audience (Figure 3 and Table 5). Three of them are addressed to an academic audience (Paper 1-3), the other three are mainly aimed at a management practitioner audience (Paper 4-6). Papers 1 and 4 are related to learning about tools and processes, Papers 2 and 5 discuss system processes, and Papers 3 and 6 describe the socio-technical developments that influence organizational learning in general. Table 6 provides an overview of the papers, and details of co-authors, current stage in the publication process, and my personal contribution to each of them.

Figure 3: Focus of the papers
Table 5: Audience and main topic of the papers

Paper 1 proposes a distinction between improvement knowledge (i.e. knowledge about lean management) and process knowledge (i.e. knowledge about NPD) and examines how the creation of either type of knowledge depends on the other. Paper 4 shows how organizations can apply improvement knowledge to continuously improve their new development processes. Paper 2 analyzes the interaction between new product development routines and lean management routines, and shows how bottom-up performance feedback drives the transformation of organizational capabilities. Paper 5 details the introduction and application of one specific lean management routine, set-based concurrent engineering, and illustrates how its principles can be integrated into the existing NPD capability. Paper 3 reports the findings of a literature review and an interview with Prof. Linda Argote on the future of organizational learning research. Paper 6 discusses a particular aspect, that of the evolution of learning practices, and their impact on the design of R&D spaces.
Table 6: Overview of the papers of this cumulative dissertation

<table>
<thead>
<tr>
<th>#</th>
<th>Title</th>
<th>Author(s)</th>
<th>Type</th>
<th>Status</th>
<th>Personal contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>The empire strikes back</td>
<td>Florian Rittiner, Stefano Brusoni</td>
<td>Academic Paper</td>
<td>Working paper</td>
<td>Study design and implementation Paper development</td>
</tr>
<tr>
<td>2</td>
<td>Recent advancements in technology and the future of organizational learning research: A conversation with Professor Linda Argote</td>
<td>Sunkee Lee, Florian Rittiner, Gabriel Szulanski</td>
<td>Academic Paper</td>
<td>Under review with Strategic Organization (SAGE Publications)</td>
<td>The first and second author contributed equally to the design and implementation of the study, and the development of the paper</td>
</tr>
<tr>
<td>4</td>
<td>Optimal product development through continuous improvement (Original title: Optimale Entwicklung mit steter Verbesserung)</td>
<td>Florian Rittiner, Nadja Haller</td>
<td>Practitioner-oriented Article</td>
<td>Published in iO Management (Axel Springer AG, Schweiz)</td>
<td>Study design and implementation Paper development</td>
</tr>
<tr>
<td>5</td>
<td>Lean innovation through set-based concurrent engineering (Original title: Schlanke Innovation durch eine alternativorientierte Entwicklung)</td>
<td>Simge Tuna, Florian Rittiner</td>
<td>Practitioner-oriented Article</td>
<td>Published in KMU Magazin (Thomas Engeli in collaboration with the EP Verlag)</td>
<td>Paper development</td>
</tr>
<tr>
<td>6</td>
<td>Workspaces for transdisciplinary collaboration (Original title: Arbeitsräume für transdisziplinäres Zusammenarbeiten: Unternehmen- oder projektspezifisches Planen und Gestalten)</td>
<td>Annina Coradi, Florian Rittiner</td>
<td>Practitioner-oriented Article</td>
<td>Accepted by KMU Magazin (Thomas Engeli in collaboration with the EP Verlag)</td>
<td>The first and second author contributed equally to the design and implementation of the project, and the development of the paper.</td>
</tr>
</tbody>
</table>
5.1 Out of the Garbage Can? How Continuous Improvement Facilitators Match Solutions to Problems

This paper builds on and extends the discussion on process management activities in NPD. We studied four companies from the automotive supplier industry in order to examine the learning processes that facilitate the introduction of lean management tools and techniques in NPD. We found that successful processes improvement activities require two distinct types of knowledge, namely improvement knowledge (knowledge about how to improve business processes, i.e. knowledge about lean management) and process knowledge (knowledge about how to develop products). Applying a ‘garbage can’ logic (Cohen, March, & Olsen, 1972), process knowledge can be understood as a stock of problems, and improvement knowledge as a stock of solutions. We found that both types of knowledge evolve according to Nonaka’s (1994) spiral of knowledge creation. Since the creation of either type of knowledge depends on the presence of the other type, the process knowledge creation and the improvement knowledge creation spirals are tightly intertwined and reinforce each other. To complicate things, these two types of knowledge are rarely mastered by the same organizational actors. Process knowledge resides in the engineers and managers who work with a particular process while improvement knowledge is typically held by process management specialists. A central task of process management is to bring these different knowledge holders together, so that they can engage in a collaborative learning process. We have seen that this complex knowledge creation process is managed by dedicated process managers. They engage in different boundary spanning and knowledge brokering activities during the knowledge creation process. Thus, process managers play a critical role in driving the co-creation of process and improvement knowledge.

In summary, this paper provides novel insights into the challenging process of learning about, introducing, and applying lean management techniques in NPD. We also describe the interplay between the different organizational actors involved in this complex knowledge creation process.
5.2 The empire strikes back

This paper builds on and extends research on organizational capabilities in order to examine the development of dynamic capabilities. Existing theory establishes that dynamic capabilities are the product of top-down learning which is triggered by external stimuli or internal feedback (Eisenhardt & Martin, 2000; Zollo & Winter, 2002). The dynamic capabilities literature focuses predominantly on the role of external stimuli (O’Reilly & Tushman, 2008; Teece, 2007), and it is only recently that capabilities researchers have started to examine the influence of internal feedback in more depth (Newey & Zahra, 2009; Zahra, Sapienza, & Davidsson, 2006). We draw on this work and attempt to shed new light on some remaining ambiguities by showing how internal feedback drives the development of dynamic capabilities through bottom-up learning.

To do so, we conducted a longitudinal case study in the R&D department of a mid-sized German high-tech company, which we will call AutomationInc. AutomationInc introduced a number of lean management tools and techniques to support its process monitoring and improvement activities. In so doing, they created a sophisticated LPD system that performs two major tasks. First, it monitors NPD performance in order to identify weaknesses in the process. Second, it supports identification of and solution to technical as well as administrative problems. Following prior research (Newey & Zahra, 2009; Winter, 2003), we understand AutomationInc’s NPD process as a zero-level operating routine. Consequently, the LPD system can be viewed as a first-order dynamic capability that systematically monitors and modifies the NPD process in the pursuit of improved effectiveness and efficiency.

By studying the nature and functioning of these internal performance feedback processes, we make several contributions to theory and practice. We identify and characterize three distinct types of internal feedback and link them to the development of the LPD system. The first type of feedback is related to the awareness of lean management by NPD actors, the second type is related to the successful identification of and solution to technical and administrative NPD problems, and the third type is related to the codification and visualization of NPD performance. We explain how this feedback influences the dynamics of the capability development process. Finally, we present detailed evidence on the structure and functioning of AutomationInc’s LPDs system. Managers can build on these insights to develop their firms’ performance monitoring systems.
5.3 Recent advancements in technology and the future of organizational learning research: A conversation with Professor Linda Argote

Paper 3 explores recent technological developments and how they influence the future of organizational learning, in both theory and practice. It builds on an interview with Professor Linda Argote (Carnegie Melon University), an influential thinker in the organizational learning field. We elaborate on some of her remarks about how recent developments in technology might change the way that organizations learn and how we can examine these learning processes at the individual level.

Under the heading of Neuroscience and organizational learning – from a micro to a neuronal level of analysis, we show that the use of technologies from the neurosciences provides us with a better understanding of how individuals make decisions and which factors influence the decision making process (Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2014; Volk & Köhler, 2012). Further developments in these technologies may allow for the examination of group processes, and thus generate a better understanding of decision making in situations that involve social interaction.

Under the heading of ICT and organizational learning – from a capture to a connect model, we discuss how recent developments in information and communication technology (ICT) influence the way that people communicate and collaborate. Technology supports learning with knowledge repository tools to capture, store, and retrieve knowledge. Research shows that people use traditional knowledge repository tools not only to exchange knowledge but also to identify who knows what, so that they can later engage in direct, offline knowledge exchange (Argote, 2011; Hansen, Nohria, & Tierney, 1999). This knowledge of who knows what is referred to as transactive memory (Ren & Argote, 2011), and technological advancements have the potential to extend these transactive memory systems beyond the boundaries of the group. In interview, Linda Argote argued that technological developments might thus push the use of ICT from a capture logic towards a connect logic. While technological advancements are enabling new ways of connecting people, and thus easing organizational learning efforts, the same developments can disconnect people by allowing for alternative work modes such as home office and mobile working (Drucker, 2002). Thus, virtual communication may increase at the expense of richer face-to-face interactions. These developments will have major implications for management practice as well as organizational learning research.
5.4 Optimal product development through continuous improvement

Original Title: Optimale Entwicklung mit steter Verbesserung

Swiss high-tech companies are known for creating innovative products of exceptional quality. The continuous improvement to products and production technologies is high on the agendas of engineers and managers. However, technological innovation is no longer enough to maintain competitive advantage in a dynamic and global market place. In order to keep abreast of ever shorter product cycles and increasing customer demands, companies need to become more effective and efficient in all organizational domains and particularly in NPD (Edmondson & Nembhard, 2009).

Paper 4 introduces several continuous improvement techniques from the lean management toolbox (Womack & Jones, 1996). These tools and techniques enable managers and engineers successfully to optimize their NPD processes. The first, and perhaps the most all-embracing technique, is Improvement Kata (see also Rother, 2010). Kata is a Japanese term which describes a choreographed pattern of martial arts movements. In the context of lean management, it refers to a sequence of activities that guides an individual, group, or organization from a current state toward a desired target condition, through iterative improvement cycles. For this process to be effective, the current state of the focal processes must be known. The lean management toolbox suggests value stream mapping, the second tool that we introduce briefly, to identify bottlenecks and waste in business processes. Once identified, these obstacles are removed by applying a standardized problem solving routine. The most famous problem solving routine is the Deming (1986) cycle, which follows the Plan, Do, Check, Act (PDCA) logic. Key to this third tool, and management of business process generally, is standardization. In order successfully to improve processes, organizations need standardized process templates. Only if the employees work according to given standards can weaknesses be identified and reliably resolved.

We posit that continuous improvement should be made an important aspect of the everyday NPD activities, and that the tools and techniques from the lean management toolbox should prove valuable support for managers in these activities.
5.5 Lean innovation through set-based concurrent engineering

Original Title: Schlanke Innovation durch eine alternativen-orientierte Entwicklung

The biggest source of waste in the context of NPD is development of the wrong technology or product (Morgan & Liker, 2006). This can happen if customer requirements are not fully understood, or a chosen design alternative proves technologically infeasible. Either case may require the development team to start afresh. The later in the project that happens, the higher will be the cost of iteration. Set-based concurrent engineering (SBCE) is a product development approach that reduces the risk of choosing suboptimal designs or at least reduces the costs related to a wrong decision.

SBCE originates in Toyota’s product development system (Sobek, Ward, & Liker, 1999; Ward, Liker, Cristiano, & Sobek, 1995). The idea behind SBCE is that the development process should start with a set of design alternatives which are eliminated according to proven facts. The set-based approach contrasts with the point-based approach where a specific design alternative is chosen early in the process. A point-based approach is risky and involves technical and strategic uncertainties. A set-based approach encourages development teams to work on different design alternatives, so that alternatives are available should a particular solution prove technologically infeasible. If the engineers are relying on one solution, as in the point-based logic, then any restart will have to be much earlier in the design process, which may jeopardize timetables. The second issue is related to strategic uncertainties. Since the development of complex products can take several years, customer requirements may change during development time. If the organization has several options in the various stages of the design process, any reorientation will be less costly. SBCE promotes two distinct techniques to reduce technical and strategic risks, namely experimentation and combination. Experimentation is based on the idea of building simple but functional prototypes as early as possible in the process. These prototypes can then be used to test the technical feasibility of a design or to gather customer feedback. The second technique encourages the combination of different sub-designs into an optimal solution. In its most extreme form, the idea of combination leads to an entirely modular product design, which allows for response to varying customer needs through the recombination of distinct modules. Thus, set-based concurrent engineering is a promising design approach for development projects with high technical uncertainty and tight timetables.
5.6 Workspaces for transdisciplinary collaboration

*Original Title:* Arbeitsräume für transdisziplinäres Zusammenarbeiten: Unternehmen- oder projektspezifisches Planen und Gestalten

To address the challenges in R&D, firms and universities rely on interdisciplinary and often international teams (Boutellier et al., 1998; Edmondson & Nembhard, 2009). University researchers have begun to question traditional disciplinary, multi- or interdisciplinary research practices that typically follow a “generalizing, decontextualizing and reductionist” approach (Wickson, Carew, & Russell, 2006). In the environmental and medical sciences, researchers tend to opt for transdisciplinarity to address research questions that involve economic, environmental, and social drivers in a more problem focused, contextualized, and consultative way (Pohl, 2008; Wickson et al., 2006). These developments change the way that people interact and collaborate which in turn, requires novel spaces where researchers, experts from the private sector, and representatives of public agencies can meet and work for varying stretches of time. This article describes the design of such a transdisciplinary research lab in the environmental science department at ETH Zurich.

We applied several qualitative and quantitative methods to study the nature of transdisciplinary research and the everyday work practices of transdisciplinary researchers. We conducted a series of interviews, non-participant observations, and an online survey to examine ongoing research activities. We also held a design thinking workshop in order to learn about the future development of the lab and the corresponding needs of the researchers. Based on this analysis, we identified six key criteria defining a transdisciplinary workspace: 1) the ability to support the creation and sharing of ideas, 2) the ability to accommodate different individual and collaborative work styles, 3) allow increased visibility of researchers’ work practices, 4) allow easier coordination of researchers’ efforts, 5) reflect the lab’s identity, and 6) foster social exchange among researchers within and outside the group. We used these criteria to design and evaluate different workspace concepts. We eventually presented two concepts from which the management team could choose.

Paper 6 highlights the importance of a functional workspace design to respond adequately to the increasing challenges created by inter- and transdisciplinary knowledge work. This applies not only to university research but also to corporate R&D.
“THE WHOLE IS MORE THAN THE SUM OF ITS PARTS.”

Aristotle (384BC – 322BC)

6 OVERARCHING CONTRIBUTIONS

This dissertation provides unique insights into the transformation of organizational capabilities and the underlying learning processes driving this transformation. Building on the evidence from five in-depth case studies and two other projects, it makes several contributions to theory and practice.

6.1 Contributions to Theory

This dissertation builds on the evolutionary theory of the firm, which defines organizational capabilities as collections of routines (Nelson & Winter, 1982; Winter, 2003). The transformation of an organizational capability corresponds to a change in the configuration of these routines (Lavie, 2006). According to Lavie (2006), this transformation process includes modification to or rejection of existing routines, as well as acquisition of new ones. The learning processes that enable these transformations fall into two broad categories of learning about tools and learning about the system. Learning about tools includes the identification and acquisition of relevant knowledge, i.e. lean management tools. The key finding here is that the successful introduction of new management tools depends on two distinct types of knowledge - improvement knowledge and process knowledge (Paper 1) – which typically reside in different and sometimes distant repositories. Learning about tools comprises those processes that lead to the integration of tools into a coherent system (Papers 1 and 2). I show that bottom-up learning driven by internal performance feedback, is an important driver of capability transformation (Paper 2).

6.1.1 Learning about tools

Learning about tools relates to the early stages of identifying valuable knowledge and transferring it to the NPD organization. Related to these learning processes, this research makes two main theoretical contributions:
First, I found that the successful optimization of business processes requires interaction between two distinct types of knowledge, namely improvement knowledge (knowledge about how to improve business processes) and process knowledge (knowledge about how to develop products). In the context of my research, improvement knowledge relates to the lean management tools which the case companies tried to introduce. In Paper 1, my co-author and I examine the acquisition of improvement knowledge from a knowledge creation perspective (Nonaka, 1994; Nonaka et al., 2000). We found that creation of improvement knowledge and the creation of process knowledge follow the same SECI process. However, the starting points of the two spirals are different. The spiral of improvement knowledge creation typically starts at the combination mode, since this the type of knowledge often stems from an outside source. The process knowledge creation spiral starts at the internalization mode since process knowledge resides in those internal actors that work with the particular process. Given that successful process improvements requires both types of knowledge, the spirals of improvement knowledge creation and process knowledge creation are intertwined. We found also that these knowledge creation processes are typically managed by dedicated process managers. It could be said that process managers help the organization to escape the classic garbage can model (Cohen et al., 1972) by actively matching solutions provided by improvement knowledge to problems that specified through process knowledge.

Second, learning from templates that originate in a similar functional context is less complicated than learning from templates from a dissimilar functional context. This is not surprising since it is well known that the transfer of knowledge and practices across contextual boundaries is challenging (Carlile, 2004; Szulanski, 1996). In general, organizations can learn from internal or external templates (Jensen & Szulanski, 2007). Learning from internal templates, that is, learning from direct experience, is suggested to be less complicated than learning from external templates, that is, vicarious learning (Argote, 2013; Levitt & March, 1988). In the particular case of introducing lean management, however, spanning organizational boundaries seems to be less difficult than spanning internal ones. Company E attempted to learn from its internal lean experts who were already working with lean in a manufacturing context. Although it had excellent access to support and to proven templates, the company faced major difficulties. This was because manufacturing is different in nature from NPD (Reinertsen & Shaeffer, 2005; Reinertsen, 2009). Thus, the tools could not just copied; they needed to be adapted (Gupta,
Hoopes, & Knott, 2014; Jensen & Szulanski, 2007). This translation process caused the difficulties in the adoption of the first lean management tools at this company (Carlile, 2004). For the company’s R&D management team it was easier to learn from external templates that had originated in an NPD context even though the access to knowledge was more difficult.

6.1.2 Learning about the system

Learning about the system is related to the integration of newly acquired lean management routines. With regard to the transformation of organizational capabilities two findings need to be highlighted.

First, bottom-up learning is an important driver of the transformation of organizational capabilities, that is, the development of dynamic capabilities. The organizational capabilities literature shows that there are different levels of capabilities (Collis, 1994; Helfat & Winter, 2011). At the lowest level, operating routines or zero-order capabilities allow the organization to survive (Winter, 2003; Zollo & Winter, 2002). At the next level, dynamic capabilities or first-order capabilities ensure the adaptation of adjacent capabilities (Winter, 2003; Zollo & Winter, 2002). By examining the interactions between operating routines, i.e. the NPD process, and dynamic capabilities, i.e. the LPD system, we found that learning occurs both top-down and bottom-up. These findings support previous research pointing to the existence of a bottom-up learning process (Newey & Zahra, 2009; Zahra et al., 2006). Hence, we suggest that the traditional top-down learning models of dynamic capability development should be complemented by a bottom-up learning process driven by internal performance feedback.

Second, the bottom-up learning process is triggered by three distinct types of internal performance feedback. The first type of feedback is related to the perceived benefits of lean management. Only if the employees are aware of the benefits of lean management will they be willing to participate and invest in the corresponding activities. In order to learn about these benefits, employees must be involved in the application of lean tools to allow them to accumulate experience (Huber, 1991; Levitt & March, 1988). At our case company (Paper 2), for an extended period of time, only top management was involved in the lean management activities with the result that the initiative had little influence on day-to-day development work. Lower management and engineering levels had no opportunities to acquire direct experience of the benefits. The second type of feedback occurs through
successful identification of and solution to NPD problems through the LPD system. Both technical and administrative problems are excellent indicators of difficulties related to underlying processes and procedures (Hackman & Wageman, 1995; Sitkin, 1992). The introduction of tools that supported the identification of and solution to problems at the level of operating routines is an important trigger for the further development of the LPD system, that is, dynamic capability. The third type of feedback is related to the codification and visualization of NPD performance through the LPD system. Organizational change requires recognition of the need for change (Adner & Helfat, 2003; Brusoni & Rosenkranz, 2014). Key performance indicators (KPIs) that codify NPD performance provide this type of feedback. Taken together, these three types of performance feedback explain, at least in part, the dynamics of dynamic capabilities development in NPD settings.

### 6.2 Further Contributions

Papers 1 and 2 elaborate on the major theoretical contributions of my dissertation; the other four papers focus on additional findings related to the functioning and value of specific lean management tools (Papers 4 and 5), the influence of recent technological developments on organizational learning processes (Paper 3), and how workspace can influence the effectiveness of NPD processes (Paper 6).

Paper 3 explores future developments in the field of organizational learning. Among other things, we discuss how recent technological developments influence how, when, and where people work (Drucker, 2002; Fayard & Weeks, 2011). This has important implications for knowledge-driven organizations. Technology enables communication and collaboration across geographical and temporal boundaries (Boutellier et al., 1998), which facilitates the inclusion of knowledge from distant sources. However, these technological developments increase the amount of virtual communication at the expense of face-to-face collaboration which is still the most effective way to share knowledge. Organizations have to rethink and adapt how they operate which might require modifications to existing routines (Papers 1 and 2) or some redesign of workspaces (Paper 6).

Paper 4 introduces some simple lean management tools and techniques that organizations can apply in order to ensure continuous improvement (CI) of their NPD processes. These CI processes represent simplified versions of the knowledge co-creation cycle developed in Paper 1. Paper 4 suggests also that CI should be an important aspect of everyday NPD activities (e.g. Bessant, Caffyn, Gilbert, Harding, & Webb, 1994). While these simple lean
management techniques provide the basics for the continuous improvement of NPD processes (Paper 4), the more sophisticated LPD system that we describe in Paper 2 corresponds to a more advanced version.

Paper 5 introduces set-based concurrent engineering (SBCE). This development approach posits that engineering decisions should be based on facts, established through careful testing (e.g. Sobek et al., 1999). SBCE promotes extensive trial and error or experimental learning to improve technical decision making. The LPD system relies on the same learning mechanisms to enable fact-based decision making with regard to managerial issues (Papers 1, 2, and 4).

Paper 6 reports the findings of a small workspace design project. We present workspace design as an enabler of innovation processes by ensuring optimal conditions for both solitary and collaborative work (Allen & Henn, 2006; Elsbach & Pratt, 2007). However, work processes are becoming increasingly virtual (Paper 3) and traditional lean management tools for example Obeya (Papers 1 and 2), may no longer be suitable. Therefore, the integration of physical and virtual spaces is a key enabler of the innovation process (Fayard & Weeks, 2011).

6.3 Implications for Practice

This dissertation provides a novel theoretical understanding of the processes of capability transformation as well as a detailed account of the everyday challenges that companies face during the adoption of management innovation. Although managers may be aware of potential obstacles, many firms struggle with the implementation of new managerial practices (Birkinshaw et al., 2008; Damanpour & Aravind, 2012). The introduction of routine-based management concepts to promote innovation in unpredictable environments seems a particularly challenging endeavor (Karlsson & Åhlström, 1996; Reinertsen & Shaeffer, 2005). I conclude with some advice for practitioners introducing new managerial practices. The issues highlighted are those that in my view distinguish successful from less successful adopters of management innovation. Although most of this advice seems straightforward, it bears repetition.
6.3.1 Involving the top management

It has been well-established that top management support is decisive for successful organizational transformations (e.g. Kotter, 1995; Zbaracki, 1998). In the companies studied, top management showed commitment to the process management activities and experimentation with lean management, by allocating budget to create process management roles, to participate in conferences, to conduct workshops, and to pursue various other activities. What separates the more successful from the less successful organizations is not so much provision of financial support but more the apparent dedication of the top management team, and the degree to which they participate in process management related activities. At some companies, process managers had to wait several weeks in order to present their ideas to senior managers. At other companies, top managers personally participated in process improvement activities. A business unit manager that moderates a week-long optimization workshop at the shop floor sends a very strong signal to the rest of the organization. Hence, managers not only have to allocate resources but they must also participate in process management related activities to show real commitment to the lean transformation process.

6.3.2 Creating dedicated organizational roles

The organizations studied created roles that are related to the improvement of processes and the implementation of lean management. Unquestionably, process managers play a significant role in the improvement of the firm’s NPD processes, and their responsibilities are multifaceted (Paper 1). As boundary spanners, process managers bridge the firm’s boundaries to facilitate the flow of knowledge into the organization through conference attendance and visits to benchmark companies. This allows them to orchestrate the application and diffusion of this knowledge within the firm through training, workshops, and written manuals. These activities take up a lot of time and process managers with other responsibilities alongside their process management tasks will find making time for them difficult. Especially in smaller firms, the process managers is often also the engineering manager or project leader. The problem is rather obvious. Customers have priority, and whenever a technical problem occurs or a project is running late, process management activities are the first to be cut back. This might pay off in the short-term but in the long run. Whenever possible, organizations should have dedicated process managers; especially in the early, turbulent phases of introducing new managerial practices.
6.3.3 Engaging in collaborative efforts

Top managers as well as process managers play a crucial role in the successful implementation and application of lean management tools and techniques. However, the rest of the organization also needs to be involved to ensure that process management ideas and practices fit with existing managerial and operational practices. Hence, various actors with diverse knowledge need to collaborate in order to improve business processes. Distributing the process management task creates commitment and decreases the workloads of individual actors. An interesting example was the mutual development of training materials. Rather than the process manager reading the chosen book and preparing the slides for a workshop, the task was split among the R&D management team. Each read one chapter of the book and prepared the corresponding training materials. Although this approach created some slack, the momentum created by this collaborative activity was impressive.

6.3.4 Acknowledging the complexity of a management concept

One of the biggest mistakes made by managers is underestimating the complexity of lean management. Ultimately, it involves not just the implementation of one management concept but the step-by-step introduction of numerous interrelated tools and techniques. Each has its idiosyncrasies, and needs to be embedded within an existing set of practices. Introducing these tools is thus a trial and error process. The organization needs to work with a tool in order to identify and eliminate emerging difficulties, and recognize its benefits. This learning process takes time and can be expedited only to a limited extent. Acknowledging the complexity of managerial concepts is crucial for the success of any implementation effort.

6.3.5 Ensuring continuity

The complexity of the introduction processes necessitates careful planning of implementation activities. Management must ensure that the organization is not overwhelmed by the introduction of new tools and the necessary adaptations to existing practice. On the other hand, it is important to ensure that the initiative maintains momentum. It may take a long time for the introduction of a new management concept to gain momentum and for the whole organization to participate in the transformation. This requires a persistent and dedicated management team that believes in the benefits of the ideas and practices being implemented.
7 LIMITATIONS AND FUTURE RESEARCH

The multiple-case study design of my thesis research allowed me to gather a wealth of data to examine the learning mechanisms that drive the transformation of organizational capabilities. However, this research has several limitations which provide opportunities for future research. Some of the limitations are related to the research design and some to the cases studied.

My findings are based on qualitative evidence from a series of interviews, observations, and focus groups with representatives from the five case companies. While qualitative case study evidence allows for the generation of new theory based on detailed analysis of a certain phenomenon, the findings are only partially generalizable (Eisenhardt, 1989; Gibbert et al., 2008). This calls for further research to confirm and extend my findings. More cases are needed to elaborate on the distinction between process and improvement knowledge, and how their co-creation is influenced by the organization of the process management activities. Similarly, my evidence indicates that the visualization of performance feedback plays a crucial role in stimulating the capability transformation process. While there is anecdotal evidence to support these findings, future research could study this effect in more detail and could quantify the different types of performance feedback in order to better understand their impact on the overall dynamics of the learning and capability transformation processes.

The five firms studied have some similarities, particularly the complexity and type of products and the industrial context in which they operate. However, there are also some differences which might explain some of the variation in the lean management adoption process. These differences allow for the formulation of a number of additional research questions.

Size: The most apparent difference among my cases is firm size. Decision making processes tend to be longer and more bureaucratic in larger organization, which might influence the speed at which an organization can experiment with and introduce new managerial practices. Future research could examine the implications of firm size and degree of formalization, on the adoption of management innovations.

Process management organization: The five organizations studied in this research have different process management organizations in place. In three cases, the process
management actors are co-located with the NPD actors; in the other two, they were in different buildings. Proximity to those actors who actually work with the focal processes seems to be key. Since I focused on specific process management events rather than everyday, informal discussions about process management topics, further research is needed to examine the influence of organizational structures and physical layouts on the implementation and deployment of process management practices.

**Process management actors:** The job of process manager requires the individual to be versatile - to be a leader, a manager, and an engineer simultaneously. This role has received little research attention. My research focused on what process managers do rather than who they are with the result that I might have missed indicators of why some organizations adopt managerial practices more quickly. Further research should take account of the individual traits of the individuals occupying process management positions.

**Top management support:** It is well-known that top management support is a critical success factor for organizational change (Adner & Helfat, 2003; McGrath, 1995). While I was able to thoroughly investigate the involvement of top management at one of the organizations, the evidence from the other four companies is less precise. However, my findings indicate that apart from the allocation of resources to process management activities, the personal participation of top managers in the corresponding activities is also important. Thus, future research is needed to examine the involvement of top managers in more detail.

**Industry membership:** I studied firms from the automotive, automation, and machine tools industries. The NPD processes in firms from these industries are very similar. The monitoring systems and process improvement tools that are in place or which they are attempting to develop are thus similar. However, the importance of specific tools and the time it takes for them to operate satisfactorily can vary. For example, the automotive industry is more process driven than the automation and machine tools industry while the automation and machine tools industries are more software driven than the automotive industry. However, this situation is changing, and these industries are becoming more similar which may allow them to benefit from each other’s management tools and techniques. More interesting, however, is what happens when such routine-based process management concepts are transferred to radically different industries. How can lean management tools and techniques be used to monitor and optimize NPD processes that
tend to be much longer and more regulated, such as in the pharmaceutical or chemical industries? What needs to be considered when lean management tools and techniques are applied to service industries such as finance, insurance, and consulting? Here, practitioners seem to be ahead of scholarly research and there is an abundance of anecdotal evidence on success factors for the application of lean management (Modig & Åhlström, 2012). Future scholarly research is needed to sort and evaluate this evidence in order to produce more rigorous advice for practitioners in different industries.

To sum up, a number of interesting questions remain unanswered: How much top management support is needed? Who is best suited to fill a process management position? How should process management teams be organized in companies of different sizes and different organizational structures? Which industries would benefit the most from routine-based improvement concepts such as lean management, and how? These questions offer promising opportunities for future research and call for more case studies and large-scale quantitative research in order to compare and contrast process management activities related to lean management in a larger set of organizations.
8 CONCLUSION

Introducing management innovation is difficult; it is not just about the adoption of one or two additional managerial practices, it requires management to make a number of individual tools and techniques work as a coherent system that fits the existing technological, cultural, and political context of the organization. The research described in this dissertation provides insights into the many-faceted process of adopting management innovation. In particular, I elaborate on the difficulties related to introducing lean management in order to transform existing new product development capabilities into lean product development capabilities. The insights provided in this dissertation show that the successful implementation of managerial practices requires different types of knowledge which in turn, requires the collaboration of organizational actors with diverse functional backgrounds at different hierarchical levels. I showed the need for performance feedback to recognize the value of newly introduced tools and to identify potential for further improvements.
9 REFERENCES


10 Appendix I – Papers

10.1 Paper 1 - Out of the Garbage Can? How Continuous Improvement Facilitators Match Solution to Problems

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OUT OF THE GARBAGE CAN? HOW CONTINUOUS IMPROVEMENT FACILITATORS MATCH SOLUTIONS TO PROBLEMS.

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Abstract

This chapter builds upon and extends the discussion about knowledge creation processes in New Product Development (NPD). We refine Nonaka’s (1994) SECI model by focusing on what and – more specifically – who triggers the transition across the different knowledge creation modes, i.e. socialization, externalization, combination and internalization. To do so, this study integrates Nonaka’s distinction between different forms of knowledge – tacit vs. explicit – with Davenport’s (1993) distinction in terms of knowledge content – process knowledge (the knowledge of how to develop products) vs. improvement knowledge (the knowledge of how to improve business processes). This chapter delivers a threefold contribution to the literature on organizational learning. First, we show that the starting point of Nonaka’s learning spiral varies with the knowledge content. Second, we argue that the learning spirals of process knowledge and improvement knowledge are connected. Finally, we will show that this link is established by specific organizational roles, which we call continuous improvement facilitators, who match, in a garbage can logic, the solutions embedded in the improvement knowledge to the problems identified through process knowledge.
Introduction

This chapter builds upon and extends the discussion about knowledge management processes in New Product Development (NPD). We refine Nonaka’s (1994) SECI model by focusing on what and – more specifically – who triggers the transition across the different learning modes, i.e. socialization, externalization, combination and internalization. To do so, this study integrates Nonaka’s distinction between different forms of knowledge – tacit vs. explicit – with Davenport’s (1993) distinction in terms of knowledge content – process knowledge (the knowledge of how to develop products) vs. improvement knowledge (the knowledge of how to improve business processes).

To oversimplify a bit, we look at process knowledge as the stock of ‘problems’ waiting for a ‘solution’, stored in improvement knowledge. Process knowledge provides the specific issues, imbalances, or errors, which enable engineers to focus their attention on specific problems and start looking for a possible solution that fits their needs. Improvement knowledge provides a stock of possible solutions to such problems. Both process and the improvement knowledge exist in different forms at different places within the organization, or outside. Both can be partly stored and made available in explicit forms through manuals and checklists, and partly mastered in tacit form by the employees or memorized in organizational routines (Nonaka & Toyama, 2003). While the explicit forms of knowledge are typically available to most organizational members, tacit knowledge is managed by heterogeneous and often distant actors. Improvement knowledge is very often available in codified forms through external sources of knowledge: consultants, academics, or professional associations. On the other hand, process knowledge is held by those who actually work with the processes. The task of process management actors is then to match the solutions to these problems. Such a matching process, as we discuss, is a complex process of learning, negotiation and adaptation, which can be, to a large extent, explained and interpreted on the basis of Nonaka’s approach.

Also, this is a classic case of a garbage can model of decision making (Cohen, March, & Olsen, 1972). As we speculate later in the chapter, process management fits in surprising well with the discussion of ‘organized anarchies’ that rely on the garbage can logic, with random allocations of solutions to problems. However, as opposed to such a random process, we propose to look at continuous improvement facilitators (hereafter: CI facilitators) as those agents that manage the matching process of solution to problems.
This chapter delivers a threefold contribution to the literature on organizational learning. First, we argue that the starting point of Nonaka’s learning spiral varies with the knowledge content. That is to say, learning about improvement knowledge starts with explicit knowledge being combined and internalized, while learning about process knowledge starts with tacit knowledge being socialized and externalized. Second, we show that the learning spirals of improvement knowledge and process knowledge are connected. Finally, we show that this link is mediated by specific organizational roles, namely CI facilitators, who deploy different knowledge brokering strategies to acquire improvement knowledge and subsequently apply it to facilitate the creation of process knowledge.

The remainder of this chapter is organized as follows. After introducing the empirical context of our study, we briefly review the literature on process management and organizational learning. Then we use Nonaka’s SECI model to describe the co-creation of improvement and process knowledge. To illustrate this process, we provide examples from our research project on lean product development. We then discuss how this framework enhances our understanding of process management activities and highlight the important role of CI facilitators in driving the spiral of knowledge creation. Finally, we suggest further avenues for the research on process management from an organizational learning point of view. We hope that our study does not only advance research, but also supports process management actors in better understanding their attempts towards the introduction of improvement initiatives.

The context: Process management in the automotive industry

Understanding the interplay of the process knowledge and of the improvement knowledge spirals matters not only for the organizational learning literature, but also for practice. We have long known that adhering to proven process templates makes operations more stable and predictable, generating efficiency gains (Adler et al., 2009). We also know that an efficiency focus may lead to undesired side effects. Adler et al. (2009) built upon the productivity dilemma identified by Abernathy (1978), to argue that short-term efficiency gains will eventually lead to long-term ineffectiveness in terms of the ability to innovate and adapt to changing environments. This tension between efficiency and effectiveness is a central dilemma in the NPD literature and practice.
In production and manufacturing settings, considerable efficiency gains were achieved by systematically working on processes and thereby striving for continuous improvements (Benner & Tushman, 2003; Womack, Jones, & Roos, 1990). Firms are striving to increase efficiency not only in manufacturing and operations, but also in white collar work, as for example new product development (Anand & Kodali, 2008; Bartezzaghi, Corso, & Verganti, 1997) or business development (Hammer, 2002; Schroeder, Linderman, Liedtke, & Choo, 2008). Karlsson and Åhlström (1996) introduced the idea that lean practices can also be applied in NPD, in order to eliminate waste (Anand & Kodali, 2008). The application of such strictly rule-based strategies to knowledge-intensive processes to achieve continuous improvement seems to be more complex and extremely challenging (Martínez León & Farris, 2011; Morgan & Liker, 2006). Indeed, process management actors still struggle to replicate these successful practices, imported from the operations domain, in research and development. This chapter intends to focus on such complexity, developing a framework which explains why the application of lean principles to NPD is difficult, and how firms are getting organized to overcome these difficulties.

To do so, we adopt an organizational learning framework that builds upon the distinction between tacit and explicit knowledge (Nonaka, 1994). To this model, we add a second analytical building block: the distinction between process knowledge and improvement knowledge. In fact, the improvement of business processes requires different types of knowledge (Davenport, 1993). The first type of knowledge is what we refer to as improvement knowledge, which is the knowledge of how to improve processes. Under this label we summarize both the knowledge about suitable improvement methodologies like lean management (Womack & Jones, 1996; Womack et al., 1990), as well as the competence to apply specific process improvement tools as for instance value stream mapping (Rother & Shook, 2003; Schulze et al., 2011). Improvement knowledge, in a way, is a stock of existing ‘solutions’ to a certain class of managerial problems, often – yet not always – framed in relatively general and abstract categories, waiting to be deployed to solve the specific problems of a specific organization. The second type is the knowledge of what to improve. We refer to this knowledge as process knowledge. This is the knowledge of the process that is to be improved. One has to know the actual process fairly well in order to understand what impedes a better process performance and to propose meaningful improvements (Rother, 2010).
Successful process improvement activities require both types of knowledge. This implies that the spiral of improvement knowledge creation and the spiral of process knowledge creation are to be connected. However, we argue that the two spirals would not necessarily and automatically follow each other as they rely on very different types of learning modes. The creation of process knowledge follows Nonaka’s conceptualization. However, the creation of improvement knowledge, although following the same sequence, begins at the combination mode. This is because the sources for improvement knowledge are typically quite explicit and located outside the firm. Hence, the CI facilitators need to span organizational boundaries to learn about them. For example, they participate in conferences and workshops to learn about possible solutions to their internal problem. In doing so, process managers collect explicit improvement knowledge that is embodied in manuals, brochures and presentations. Yet, these solutions are often unrelated to the specific context in which the knowledge is to be applied. Hence, CI facilitators must customize this explicit improvement knowledge so that it matches the needs of their firms. Company-specific tacit knowledge serves as guideline and yardstick at this stage. The next step refers to the application of the improvement knowledge to create new process knowledge, which is the main goal of improvement initiatives. During this process new improvement and process knowledge is co-created. The final step in our model represents the articulation and diffusion of the knowledge, which leads to separate, but interacting spirals of improvement and process knowledge creation.

As Von Krogh et al. (2012) argue, this depends on the extent to which a group can create new knowledge and on the degree to which knowledge assets can be mobilized. Hence firms need somebody who is creating the field in which the different actors meet to generate organizational level learning (Nonaka, 1994). Many organizations have a special process management unit that are in charge of such a coordinating function. At other companies, in particular smaller ones, there are single employees in charge for those process management activities, which is then often a part time job.

To illustrate these process management activities, we show examples from four automotive supplier companies that are about to implement lean management in their product development departments. All of them are located in the German-speaking area and participate on a larger research project on lean product development (LPD). The firms have dedicated personnel who is responsible for the management and improvement of NPD processes. We refer to these employees as CI facilitators, as their main task is to ensure the
continuous adaptation of the companies' NPD processes to meet ever increasing requirements. Two companies, hereafter named Company A and Company B, have process managers organized in a staff function. At another company, Company C, the process manager works part-time on process management activities and is reporting directly to the head of R&D. The last company, Company D, employs an hybrid organization where the process manager is reporting directly to the division head, but also part of a company-wide process management organization that is setting standards together. We have been able to study the companies for one and a half years at various occasion. We visited the companies to do interviews and observations, we organized a number of workshops in which the companies discussed different topics related to the introduction of lean principles to NPD. In doing so, we were able to observe how these companies go about the tedious introduction of managerial innovations (Birkinshaw, Hamel, & Mol, 2008), i.e. the attempt to implement lean management to new product development. We identify the key actors in the introduction process and characterize their role in the knowledge creation process.

**Process management and knowledge requirements**

Benner and Tushman view process management as "concentrated efforts to map, improve, and adhere to organizational processes (2003:238)." Over the decades, a number of concepts have been developed to support these process management attempts. Total Quality Management (TQM) became prominent in the 1980s (Hackman & Wageman, 1995; Repenning & Sterman, 2001; Westphal, Gulati, & Shortell, 1997), Six Sigma in the 1990s (Pande & Holpp, 2001) and more recently Lean Management (Womack & Jones, 1996; Womack et al., 1990). The elimination of waste and the root cause of process variability is thereby one of the key elements (Ittner & Larcker, 1997; Rother, 2010). The benefits from those process improvement activities are numerous, including increased yields, less rework and waste, tighter organizational linkages and thereby faster product development along with shorter delivery times (e.g. Armistead, 1999; Karlsson & Åhlström, 1996). Nevertheless, critical voices are saying that those initiatives have hardly any impact on organizational and financial performance (Benner & Tushman, 2003; Ittner & Larcker, 1997; Powell, 1995). Furthermore, process improvement activities are still seen as additional work that prevents engineers from doing their "real" work (Repenning & Sterman, 2002). Engineers are mainly interested in developing technically superior products and perceive the advancement of the organization as a management task (Nilsson-Witell, Antoni, & Dahlgaard, 2005).
1 Improvement knowledge

Knowledge about improvement methodologies and tools is an important ingredient of process improvement activities (Davenport, 1993). From a process management perspective, this knowledge describes how to best improve business processes. We label this type of knowledge 'improvement knowledge'. Improvement knowledge is hierarchically structured. We observe both general principles, e.g. eliminate waste, and batteries of tools to implement those principles, e.g. value stream mapping (Rother & Shook, 2003; Schulze et al., 2011). For example, Karlsson and Åhlström (1996) and Anand and Kodali (2008) list a number of such tools and techniques that support lean management efforts. Many of them support problem-solving activities. In garbage logic terms, they represent concrete solutions to specific problems. These tools and techniques are well described in books, cases, examples and manuals.

2 Process knowledge

The knowledge of NPD processes and their current condition is what we name 'process knowledge'. This is the knowledge of what to improve, which is hold by process owners and process users. The former are typically middle or top managers. Process users are the engineers who actually develop the products. Process knowledge tells us what problems matter to specific people within different functions. Feldman (2000) identifies "the potential for change in the internal dynamics or the routine itself, and in the thoughts and reactions of the people who participate in the routines (2000:626)." This implies that the need for improvement is best sensed by those who actually work with the processes. Similarly, Nelson and Winter (1982) argue that problem solving is activated by puzzles or anomalies that arise during routine operations. Sometimes, these anomalies can be retrieved in explicit form through process performance data. However, the measurement and documentation of development process performance is cumbersome and the effort put into collecting such data varies greatly among firms. Hence, directly involving the engineers who are working with the processes is an important and efficient way for process management actors to learn about actual practices and gather first hand performance information.

3 Process management as garbage can process

Cohen and March (1972) introduce the garbage can model to explain decision making in what they called organized anarchies. These organizations are characterized by three
general properties. First, these organizations are guided by problematic preferences, which means that they have inconsistent or ill-defined preferences. The second property is unclear technology, which means that the company operates according to simple trial-and-error procedures. Finally, these organizations are characterized by fluid participation, which implies that the amount of time and effort that participants devote to different domains varies. Cohen and March describe the organization as "a collection of choices looking for problems, issues and feelings looking for decision situations in which they might be aired, solutions looking for issues to which they might be the answer, and decision makers looking for work (1972:2)".

Our case study companies share the characteristics of organized anarchies. Conflicting preferences exist on a number of scales. Furthermore, when we refer to improvement knowledge as the 'technology' that is to be mastered by the process management organization, we may well speak of an 'unclear technology'. Indeed, the knowledge that is required to successfully improve NPD process is often not available within the boundaries of the firm. Therefore, improvement activities resemble trial-and-error procedures with uncertain outcomes. Even if CI facilitators reach outside the organization and learn about different improvement methodologies and the corresponding tools, it remains unclear whether their efforts lead to the expected results. Last, with respect to the third property of organized anarchies, CI facilitators involve engineers and designers in their improvement initiatives only when deemed necessary. Hence, the participants in process management activities vary from case to case. Process management entails a number of decisions to be taken by a variety of organizational actors. The efficiency and effectiveness by which these decision are taken depends on how successful the organization can activate its members and direct their attention to the problems at hand (Cohen et al., 1972).

**Organizational learning and knowledge characteristics**

According to Polanyi (1966), we know more than we can tell. This observation gave rise to the development of various characterizations of knowledge (e.g. Gourlay, 2006). For example, Nonaka and Takeuchi (1995:58-59) describe knowledge as 'a meaningful set of information', Myers (1996:2) calls organizational knowledge 'processed information', and Davenport et al. (1998:43) describe knowledge as 'information combined with experience'. These definitions indicate that knowledge is somehow richer than information and propose a hierarchy in which knowledge is seen as the more advanced construct (Alavi & Leidner,
The discourse about information and knowledge, and in particular how they are set apart from each other, is inherently related to the discussion about how easily knowledge can be articulated. Knowledge that can be easily articulated and transferred is referred to as explicit knowledge (Nonaka, 1994; Polanyi, 1966). Tacit knowledge, on the contrary, stands for knowledge that is difficult to articulate and that can be shared only with great difficulty (Nonaka, 1994; Polanyi, 1966).

Many have argued that organizational learning is the most important factor to achieve competitive advantage in product development. The most widely used model for organizational knowledge creation is probably the SECI framework, for which Vaccaro et al. (2009) report references to a variety of research fields such as management information systems, organization studies, strategic management and technology management and policy. Gourlay (2006) notes 543 citations for Nonaka's 1994 paper in management journals until 2004. This number increased to 2263 until early 2012⁵, showing the sustained attractiveness of the model. In this chapter, we apply the model to further examine and visualize the process of knowledge creation that is underlying process management in new product development.

Nonaka and Toyama (2003) provide the link to process management activities as they use the framework to analyze Toyota's continuous process innovation in manufacturing. One of their key findings is that workers have to share their knowledge in order to be able to make improvements to the process. Dyck et al. (2005) confirmed Nonaka's four-phase knowledge creation process empirically by using data from the examination of product development activities of an automotive company. Unlike in this chapter, Nonaka and Toyama (2003) and Dyck et al. (2005) focused on technical product and production knowledge, rather than development process knowledge.

Given the distinction between improvement and process knowledge on the one hand, and explicit and tacit forms of knowledge on the other hand, process management organizations have to master four distinct types of knowledge. In table 1, we link the four types of knowledge we consider to their main repositories. Explicit forms of improvement and process knowledge are easily accessible, for example through process databases or manuals on the intranet. Tacit knowledge is more difficult to access, as it is held by a variety of organizational actors. In this chapter, we refine Nonaka's model of knowledge

⁵ According to the ISI Web of Science citation report in May 2012.
creation to be able to describe the interactions among those four knowledge types, which are in one way or another required to successfully improve organizational processes.

Table 1: Distinct types and repositories of improvement and process knowledge

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<th>Improvement Knowledge</th>
<th>Process Knowledge</th>
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<tr>
<td><strong>Explicit Knowledge</strong></td>
<td>Manuals, Guidelines, etc.</td>
<td>Process descriptions, Development manuals, etc.</td>
</tr>
<tr>
<td><strong>Tacit Knowledge</strong></td>
<td>CI facilitators (Process managers)</td>
<td>Process owners (middle and top management), Process users (engineers)</td>
</tr>
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Nonaka and Toyama (2003) argue that despite the ever growing body of research on organizational knowledge creation, “we are still far from understanding the process in which organizations create and utilize knowledge (Nonaka & Toyama, 2003:2)”. Much of the literature on organizational knowledge creation is mainly concerned with the particularities stemming from the distinction between explicit and tacit forms (Nonaka, 1994; Nonaka, Toyama, & Konno, 2000), and between individuals and organizations as the main unit of knowledge creation (Grant, 1996; Nonaka, 1994). This literature is focusing on different knowledge forms rather than varying knowledge content. We argue that the influence of knowledge content has been underappreciated in the knowledge creation literature so far.

The co-creation of improvement and process knowledge

We argue that the creation of improvement and process knowledge follows a four stage process that leads to two separate, but interacting spirals of organizational knowledge creation. The first stage relates to the acquisition of improvement knowledge, which typically originates outside the firm. The second stage describes the integration of the newly acquired improvement knowledge into the organizational context. The third stage corresponds to the actual co-creation of improvement and process knowledge, through the interaction of improvement and process knowledge holders. The final step refers to the subsequent externalization of the knowledge. In the following paragraphs we develop the four-stage model step-by-step and illustrate it with examples from our research project on lean product development.
Stage 1 – Acquisition of improvement knowledge (combination)

The first stage of our model describes the acquisition of improvement knowledge (I_E). At the very beginning of introducing lean management into product development there is typically very little knowledge available inside the organization. CI facilitators have to reach over the boundaries of the firm to gather adequate improvement knowledge. The CI facilitators act as brokers, who enable the flow of improvement knowledge into the organization. Fernandez and Gould define brokerage as "a relation in which one actor mediates the flow of resources or information between two other actors who are not directly linked (1994:1457)." This particular type of brokering relation is known as boundary spanning (e.g. Fleming & Waguespack, 2007; Tushman, 1977) or gate keeping (e.g. Fernandez & Gould, 1994). The concept of brokerage has been thoroughly examined by a number of scholars (among others Burt, 1992, 2005; Granovetter, 1973; Lingo & O'Mahony, 2010; Obstfeld, 2005; Simmel, 1950). Innovation performance is positively influenced by the extent to which organizations, teams and individuals can access knowledge across boundaries (Tortoriello & Krackhardt, 2010), as it was shown in a number of studies on product innovation (Allen & Cohen, 1969; Katz & Tushman, 1979; Tushman & Scanlan, 1981).

The four sample companies started their journey in the top-left quadrant of Figure 1, when they joined a purpose-designed workshop on lean product development. Process management actors at all companies, mainly CI facilitators, got an identical reading list and started working with the very same material on lean thinking. CI facilitators read books (in particular: Morgan & Liker, 2006; Reinertsen, 2009; Rother, 2010) and a number of selected articles (among them: Haque & James-Moore, 2004; Reinertsen & Shaeffer, 2005; Sobek, Liker, & Ward, 1998). On this basis, a number of workshops were organized to discuss issues and problems. Moreover, CI facilitators as well as managers from the participating companies attended a conference on lean management, where they learned about the experience of other companies that work with the lean management approach.

These activities exposed them to the explicit improvement knowledge, as articulated in books, articles, examples, case studies and conference proceedings. Although the material had been discussed in detail, the discourse remained on a rather general and abstract level. These initial activities thus represent the transfer, combination and diffusion of explicit knowledge and correspond to the activities that take place at the combination mode of
Nonaka's model (Nonaka, 1994). At this stage, the acquisition of improvement knowledge in explicit form represents the main activity of the CI facilitators.

![Figure 1: Stage 1 of the model of knowledge co-creation](image)

**Stage 2 – Contextualization of improvement knowledge (Internalization)**

At the first stage, CI facilitators introduce new improvement knowledge in the organization through their boundary-spanning activities. Yet, such knowledge is kept within the process management organization. CI facilitators have to make the R&D organization aware of this newly acquired improvement knowledge and identify possibilities to apply it. In the words of a CI facilitator at Company A: "I would say that I have several roles. On the one hand, I have to keep the overview [to identify improvement needs] and on the other hand, I have to try to sell the [process management] function to the different R&D units, in order to gain a certain acceptance." Lean management, similar to TQM or Six Sigma, presents a comprehensive improvement methodology that is difficult to implement as a whole (Westphal et al., 1997). CI facilitators need to identify those elements that are likely to deliver the ‘quick wins’ necessary to obtain support and acceptance. This is the stage when the range of possible solutions embodied in the newly acquired improvement knowledge, is broken down in simpler tools, which are matched to specific engineering problems.

To do this, CI facilitators involve further organizational actors. They have to convince those people who might benefit from their initiatives to support and sponsor them. They engage process owners who are responsible for the optimization of organizational processes (Trkman, 2010). Through a long and often time consuming process of meetings,
seminars, and informal discussions, CI facilitators learn how engineers in their organizations perceive lean management, which aspects they favor, which they dislike, and why. The interactions with those who hold process knowledge (\( P_T \)), facilitate the internalization of improvement knowledge (\( I_E \)) by the CI facilitators as they represents a reality check in the light of the organizational characteristics. Part of the newly formed tacit improvement knowledge (\( I_T \)) is, for instance, the knowledge about which problems to prioritize in order to solve them with the tools made available by the lean management toolbox. Similar to Dyck et al. (2005) and Vaccaro et al. (2009), we observed that the internalization mode is triggered by 'learning-by-doing': explicit and external improvement knowledge needs to be applied to be really made relevant to organizational members.

The adaptation and implementation of the Obeya concept (for more information see: Morgan & Liker, 2006; Oppenheim, 2004) at Company C is an excellent example to illustrate the internalization of explicit improvement knowledge (see top-right quadrant in Figure 2).

The CI facilitator learned about the Obeya at a workshop with other CI facilitators. She was convinced that having all relevant development data available at one place would help them to fasten their development process. At different occasions, she presented the idea to the company's middle and top management. She learned that transforming one of their meeting rooms into an Obeya is not feasible. The reason was simple; there was not enough office space available. Through the many discussions, however, she learned that there is indeed a need for visualizing critical project information. Thus she adapted the concept of the Obeya to match the company's requirements. Together with one middle manager, she initiated the creation of a so-called "LEAN-corner", to display information about ongoing improvement initiatives, preliminary results and general development information. This corner was perceived very well by the employees and not much later all departments in R&D installed such a board.

The internalization of improvement knowledge by the CI facilitators goes hand in hand with its diffusion into the R&D organization and the familiarization of relevant process management actors. Through the education of the process owners and other management representatives, the CI facilitators gain credibility for their initiatives and further support for the use of the methodology.
Also at this stage, CI facilitators act as knowledge brokers. However, their role is slightly different. At stage 1, they acted as boundary spanners to activate the flow of explicit improvement knowledge into the organization. At this stage, they contextualize this knowledge (I_E) considering tacit process knowledge (P_T), which is held by process owners and users, into tacit improvement knowledge (I_T). Burt (2004) distinguishes between four levels of brokerage through which an organizational actor can create value. The first level is making people on either side of a structural hole aware of each other's interests. The second level refers to the transfer of best practices between two groups. Brokers at the third level draw analogies between groups that are at first sight irrelevant to one another. The fourth level refers to the synthesis of knowledge from different groups. The boundary spanning activities at the first stage of our model refer to the second of Burt's (2004) levels. CI facilitators collect knowledge about lean management, which we can refer to as codified best practice from other companies such as Toyota (Morgan & Liker, 2006; Womack & Jones, 1996), and transfer it into the own organization. The activities at the second stage are more complex. The contextualization of improvement knowledge requires the synthesis from both improvement and process knowledge, in order to determine which elements of the lean management methodology might as well work for the own company. This brokering activity thus matches the fourth level of Burt's (2004) typology.

Stage 3 – Co-creation of improvement and process knowledge (Socialization)

The third stage of our model describes the actual application of improvement knowledge (I_T), in order to enhance process knowledge (P_T). This is the central step through which
simultaneously new improvement knowledge and process knowledge \((I_I^+ \text{ and } P_I^+)\) are created. CI facilitators apply their improvement knowledge and learn how to advance their tools and methods. Process owners and users benefit from optimized processes through the application of improvement methods introduced by the CI facilitators. Most of the knowledge that is involved at this stage is tacit, although the companies have descriptions for most of their processes. Nevertheless, these explicit descriptions rarely account for the complexity of process knowledge. Furthermore, engineers who are developing products for years do no longer refer to these process descriptions as they know the process by heart. One engineer at Company C put it this way: "That is my experience and I know more or less how the processes look like. However, I cannot tell whether they correspond to the process that we find somewhere on the intranet." The notion of more-or-less is what often makes the difference. The growing variation in the way of working is not uncommon, as organizational routines naturally evolve over time (Nelson & Winter, 1982). Hence, actual routines often deviate from the standards that have been set earlier on (Nelson & Winter, 1982). Process management activities, in particular the mapping and subsequent improvement of processes (Benner & Tushman, 2003), capture those deviations and, if necessary, provide the tools to optimize the corresponding processes. However, this is only possible, if those people who know about the current routines and their inadequacy are involved in the improvement activity. Hargadon and Bechky (2006), for example, state that "when participants come together in collective problem-solving efforts, one person often has a good understanding of the problematic situation, while others have potentially relevant ideas and experiences to contribute (2006:492)". CI facilitator offer methods and tools to facilitate this dialogue. As mainly tacit knowledge is shared, the main part of knowledge creation at this stage correspondingly happens through socialization (Nonaka, 1994).

Value stream mapping (VSM) provides an excellent example to describe the complex activities at this stage. We provide a short illustrative episode from a value stream mapping workshop at Company A and the subsequent improvement of the prototyping process.

There was the general perception that processes at the prototyping workshop are not as smooth as they could be. The CI facilitator identified the need for a thorough analysis of the working processes. He invited relevant stakeholders and organized a value stream mapping workshop to visualize the current processes. Eight employees from all relevant functions in prototyping and two employee from the development organization,
representing the internal customer, participated. As this was the first VSM workshop for them, the CI facilitator invited two external experts from the university to assist him in conducting the workshop. During the workshop the participants identified 22 weaknesses of the current process. Of these 22, one issue seemed to be particularly pressing to the participants.

Prototypes are shipped weakly to the OEM (Original Equipment Manufacturer) for testing and there was the perception that all of them are brought to quality inspection and subsequent shipping on Friday afternoon, which leads to an accumulation of work and eventually to delayed shipment. There was a lot of discussion about this issue, but the actual root-cause could not be identified during the workshop. Thus the CI facilitator and the employee who is responsible for testing, performed a more thorough processes analysis and collected data about when the prototypes actually arrive. They found that delays are not caused because too many prototypes arrive on Friday, but because of the many set-up procedures that were necessary as prototypes of different dimensions arrived randomly.

Eventually, the solution was that the testing worker ask on Monday morning which prototypes that are to be tested and shipped in that week. By doing so, he can schedule the upcoming testing activities well in advance and thereby avoid congestion towards the end of the week. The improvement of the process, which is only a minor one, saves them up to 4 hours in set up time. Without the VSM workshop, however, they would have continued as before.

In this example, optimizing the process for prototype testing refers to creating enhanced process knowledge ($P_T^+$). The successful application of the VSM tool and the subsequent analysis of the process through the collection of additional data, as proposed by Rother (2010) for instance, can be seen as enhanced or justified improvement knowledge ($I_T^+$). The success of the workshop is a strong signal to the R&D organization that the methods and tools employed by the process management organization have a positive influence on product development performance.

In this short episode, we can see how versatile the role of CI facilitators is and how they facilitate the co-creation of improvement and process knowledge, which is driven by different types of brokering activity. First, the CI facilitator identified the need for a more thorough process analysis through the monitoring of the activities within the R&D department. On this basis, he proposed and organized the VSM workshop and invited all
relevant stakeholders (he acted as a coordinator). Then, he brought the knowledge about VSM as an improvement tool into the organization (stages 1 and 2) and identified a promising opportunity to apply it (stage 3). In doing so he acted as boundary spanner during stage 1, as a broker who synthesizes different types of knowledge during stage 2, and as coordinator during stage 3 (represented in the bottom-right quadrant of Figure 3). Also, the CI facilitator brought external experts into the firm to support the first VSM workshop in order to benefit from a much broader set of experiences with the VSM method (he was a gate keeper again). Thus, the CI facilitator promoted the sharing of experience between two distant organizational functions, namely the prototyping organization and the development organization (he acted as coordinator). Crucially for the internalization phase, the CI facilitator acted as itinerary broker (Fernandez & Gould, 1994) between the different workers from the prototyping workshop, getting involved directly in solving a specific problem. As the battle lines were drawn within the shop floor, the VSM workshop and in particular the subsequent process analysis by the CI facilitator allowed for a constructive dialogue on the prototyping process.

The conversion from tacit to tacit knowledge happens through the interaction between individuals (Nonaka, 1994). Nonaka et al (2000) argue that "tacit knowledge can be acquired only through shared experience, such as spending time together or living in the same environment (2000:9)". Close physical interaction through the sharing of time and space is important to share the context and form a common language among participants (Nonaka et al., 2000). It is the task of the CI facilitator to create this kind of environment that allows the participants to share their tacit knowledge and improve their understanding of their development work that will eventually lead to better processes and increased performance. The knowledge about how to create such an environment is exactly what we refer to as improvement knowledge.
Stage 4 – Externalization of improvement and process knowledge (Externalization)

The fourth stage in our model (see bottom-left quadrant of Figure 4) represents the externalization of the enhanced improvement and process knowledge that has been created in the previous stage. Externalization refers to the articulation of tacit knowledge into explicit forms that can easily be shared and diffused (Nonaka, 1994; Nonaka et al., 2000). Visualization methods such as value stream mapping eases the articulation of tacit knowledge. The visual map represents an abstract version of the newly created tacit knowledge ($P_T^+$) and helps to convey it to other workshop participants. Nevertheless, such a map is of limited use to people who did not participated in the workshop. The tacit knowledge that comes out of the socialization mode has to be externalized and combined with explicit knowledge accounts, such as the visual map from the workshop and other existing process documentation. These explicit accounts of the tacit knowledge ($P_E^+$) can then be used to communicate and educate the wider R&D organization about the workshop results and subsequent improvements of the NPD process.

CI facilitators learn a lot when they apply one of the improvement tools. During the workshop (at stage 3), CI facilitators thus acquire new improvement knowledge ($I_T^+$). After the workshop this knowledge is as well externalized and stored in explicit forms ($I_E^+$), for example as best practices, for future applications.

At the fourth stage, the CI facilitators play again a critical role. They are in charge of reformulating both the newly acquired improvement and process knowledge and making
available to those who will work according to those instructions. Also, in the fourth step the process of improvement and process knowledge flows into two separate spirals of knowledge creation, following Nonaka's model (Nonaka, 1994).

Figure 4: Stage 4 of the model of knowledge co-creation

**Discussion**

This chapter contributes to the existing literature on process management and organizational learning in three distinct ways. First, we show that process management depends on two distinct types of knowledge – improvement and process knowledge. Second, we disentangle and examine the process through which these two types of knowledge are simultaneously created. Third, we show the significant role that dedicated process management actors, in particular the CI facilitators, play in driving the knowledge creation process.

We have argued that successful process management activities depend on two distinct types of knowledge: the knowledge of how to effectively improve business processes, i.e. improvement knowledge, and knowledge of what to improve, i.e. process knowledge. We are able to show that the creation of either type is dependent on the other one, but also exhibit important differences in terms of their starting point and the type (explicit vs. tacit) of knowledge they chiefly rely on. We believe that this line of reasoning is important to understand how firms escape the classic garbage can model. The key function played by our facilitators is indeed one of matching ‘solutions’ (as embedded in management methods) to ‘problems’, as revealed to engineers as they go about their everyday design activities. To understand which solutions match to which problems, CI facilitators act as
brokers. And they do so in various ways (e.g. they connect, they span, they synthesize) according to the specific phase of the Nonaka’s spiral in which they operate.

Implications for management

We disentangle and illustrate the process of co-creation of improvement and process knowledge. R&D managers benefit from a better understanding of this complex process in a number of ways. Knowing that there are two types of knowledge that have to be considered allows them to organize their process management activities accordingly. They know which organizational actors are to be involved in the process. Nonaka and Toyama (2003) argue that in order to understand knowledge creation it is important to understand the interactions among the individuals and work groups involved in the process. Recently, von Krogh et al. (2012:254) stressed that the "collaboration between individuals is an essential part of organizational knowledge creation." However, these individuals and workgroups may well have different interests and goals, which is a central property of anarchistic organizations as which process management can be framed (Cohen et al., 1972). For CI facilitators, process improvements are the main part of their work and what they are evaluated for. In order to successfully improve processes, however, they depend on the support of the NPD organization whose main target is the development of products. These contradicting goals might lead to tension in the process management process, which requires the top management to clearly signal that the activities of the CI facilitators are necessary and valuable to the organization. Leadership is thus an integral part of organizational knowledge creation and depending on the perspective, leadership can either be something that is attributed to a central authority or something that is distributed among different individuals (von Krogh et al., 2012). The shift towards distributed leadership can be attributed to an increased division of labor, new interdependences and coordination between task, and multiple team practices that shape knowledge-intensive work (Gronn, 2002; von Krogh et al., 2012). In the model that we propose, leadership is clearly distributed among different roles and tasks are distributed among different actors. Process management actors, before all CI facilitators, play unquestionably a significant role in the improvement of a firms NPD process landscape. As boundary spanners they reach over the boundaries of their firms to facilitate the flow of improvement knowledge into the organization. Subsequently, they orchestrate its application and diffusion within the organization. Nevertheless, they need the approval of the upper management to engage in these boundary spanning activities. We hope that our findings support process management
actors in finding the necessary backing for their initiatives, and gaining recognition for their efforts.

Limitation and future research

This chapter clearly raises more questions than it is able to answers. Further research is needed to clarify the micro-level activities of organizational learning, and the interplay of organizational vs. individual level factors. One crucial step that we have not given adequate attention too, is the initial selection of the specific tool to implement to gain credibility internally, what we referred to as the ‘quick win’. In choosing it, the CI facilitator plays a tremendously important role: they ‘simplify’ a whole management philosophy to help their colleagues visualize and perceive its advantages. Further research is needed to understand how do they actually choose the specific tool to first implement? Moreover, how do they transfer what they learns from its implementation to the next stage? Why so often, despite the initial success, they fail to give continuity to the process (witness the wealth of studies highlighting the lack of diffusion of lean management as an overall philosophy, and its only partial success as a set of tools and techniques). Why is it so hard to learn how to match existing solutions to actual problems? Why is it so hard, in other words, to escape from the garbage can? In this chapter we have analyzed the very first step of this process, the introduction of first specific tool, that sets the stage for the subsequent introduction of further tools and eventually the whole improvement philosophy.

Conclusion

Successful process management activities depend on two distinct types of knowledge, namely improvement and process knowledge. The creation of either type depends on the other one, which means that the two spirals of improvement and process knowledge creation are inherently connected. Hence, process management is a complex task. CI facilitators, a specific and vastly understudied organizational role, play a very important function as they facilitate the flow of improvement knowledge into the firm and orchestrate its application to the benefit of the wider R&D organization. The quest for more efficiency and effectiveness in the fuzzy front end of NPD goes through a deeper understanding of what facilitators do, and how they do it. Professor Nonaka’s work provide robust and relevant foundations to such an endeavor.
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10.2 Paper 2 - The empire strikes back

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THE EMPIRE STRIKES BACK

How bottom-up learning from operating routines drives the development of dynamic capabilities

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Working paper

Abstract

Despite a growing body of research on dynamic capabilities, various unresolved issues remain; for example, how they come into being. In this paper, we build on and extend the research that examines the origin and development of dynamic capabilities to shed new light on the questions of where they come from and how they develop. We provide evidence from an inductive, longitudinal case study that shows that bottom-up learning, which is influenced by performance feedback from lower-level operating routines, is an important driver for the development of dynamic capabilities.

Key words

Dynamic capabilities, operating routines, new product development, bottom-up learning
Introduction

Despite more than two decades of research on dynamic capabilities, some important conceptual issues remain unsolved, for example, how dynamic capabilities come into being and evolve over time (Ethiraj, Kale, Krishnan, & Singh, 2005; Foss, Heimeriks, Winter, & Zollo, 2012). Existing theory establishes that dynamic capabilities are the product of top-down learning, which is triggered by external stimuli or internal feedback (Eisenhardt & Martin, 2000; Zollo & Winter, 2002). Although the dynamic capability literature indicates that internal feedback influences this learning process, it focuses predominantly on external stimuli (O’Reilly & Tushman, 2008; Teece, 2007). Only recently capability researchers started to examine the influence of internal feedback more carefully (Newey & Zahra, 2009; Zahra, Sapienza, & Davidsson, 2006). We draw on this work and attempt to remove some of the remaining ambiguities by showing how internal feedback drives the development of dynamic capabilities through bottom-up learning.

To do so, we build on the evolutionary theory of the firm (Nelson & Winter, 1982). Evolutionary theorists view organizational capabilities as being embedded in an organization’s routines (Pentland, Feldman, Becker, & Liu, 2012). They further distinguish between two archetypes of organizational capabilities, namely operating routines and dynamic capabilities (Helfat et al., 2007; Zahra et al., 2006). Central to the definition of dynamic capabilities is the hierarchical, top-down relationship between them and the operating routines that they renew and adapt (Lavie, 2006). Zollo and Winter (2002:340) express this top-down relationship in their definition of a dynamic capability as “a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness”. Focusing too much on this top-down relationship leads to the omission of bottom-up learning driven by internal feedback. We know from organizational learning theory that performance feedback indeed plays a crucial role in the advancement of capabilities (Cohen & Levinthal, 1990; Levitt & March, 1988). We thus propose to complement existing top-down learning models by a bottom-up learning process, which is triggered by performance feedback from the operating routines.

We examine this bottom-up learning process by studying how firms monitor their operating routines to thereby learn about the adequacy and performance of their dynamic capabilities. For this, we conducted an inductive, longitudinal case study in the research
and development (R&D) department of a mid-sized German high-tech company (hereafter: AutomationInc). AutomationInc introduced a number of (lean) management tools and techniques to support their process monitoring and improvement activities. In doing so, they created a sophisticated lean product development (LPD) system that performs two major tasks. First, it monitors the NPD performance in order to identify weaknesses in the process. Second, it supports the solution of the identified technical and administrative problems. AutomationInc is a uniquely insightful example of how an organization learns bottom-up from internal performance feedback to drive the development of its dynamic capabilities.

By studying internal performance feedback, we are able to make several contributions to both theory and practice. First, we identify and characterize three distinct types of internal feedback and link them to the development of the LPD system. Second, we explain how this feedback influences the dynamics of the capability development. Finally, we present detailed evidence on the structure and functioning of AutomationInc’s LPD system. In doing so, we show how firms benefit from improved coordination of their NPD activities through increased transparency of the process and stronger incentives for the improvement of their NPD activities through codified and visualized performance feedback. Our case study can thus serve as a template for practitioners that intend to introduce similar monitoring systems.

The remainder of this paper is organized as follows: First, we set the stage for our discussion by briefly reviewing the literature related to the development of dynamic capabilities. Second, we introduce our research design. Then we describe AutomationInc’s LPD system and illustrate the three internal feedback loops. Fourth, we discuss how this performance feedback drives the development of the LPD system. We conclude with some implications for practice, the limitations of our study, and promising avenues for future research.
Theoretical Background

In this paper, we build on the evolutionary theory of the firm that views organizational capabilities as being embedded in an organization’s routines (Nelson & Winter, 1982; Pentland et al., 2012). Researchers in this field distinguish between two types of organizational capabilities (Helfat et al., 2007; Zollo & Winter, 2002). Operating routines allow an organization to “earn a living now” (Winter, 2003:992), but they do not ensure sustained competitive advantage (Collis, 1994). In order to match changing internal and external conditions, an organization must continually adapt and reconfigure its operating routines (Helfat et al., 2007). This requires a different set of capabilities that are commonly known as dynamic capabilities (Teece, Pisano, & Shuen, 1997). Teece et al. define a dynamic capability as “the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments” (1997:516). Zollo and Winter (2002) stress the routine character of dynamic capabilities and make the understanding of routines as repeated patterned activities (Feldman, 2000; Nelson & Winter, 1982) part of their definition of a dynamic capability as “a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness” (Zollo & Winter, 2002:340). In this sense, dynamic capabilities refer to an organization’s capacity to renew or develop its operating routines to achieve superior organizational performance (George, 2005; Zahra & George, 2002). Teece et al.’s (1997) as well as Zollo and Winter’s (2002) definition indicate a hierarchical relationship between dynamic capabilities and operating routines. Dynamic capabilities are understood as higher-order capabilities that act upon lower-order operating routines (Collis, 1994; Winter, 2003). In fact, both Collis (1994) and Winter (2003) indicate a hierarchy “ad infinitum” by arguing that next higher-order capability, which influences the lower one, always exists. More recently, Ambrosini, Bowman, and Collier (2009) suggest a similar top-down learning model where they further distinguish between incremental, renewing, and regenerative dynamic capabilities.

While the top-down relationship between dynamic capabilities and operating routines is well established in the literature, much uncertainty still exists about the origin of dynamic capabilities and the learning mechanisms that lead to their development (Foss et al., 2012; Helfat et al., 2007). The general answer to this question is that dynamic capabilities develop from path-dependent organizational learning (Ethiraj et al., 2005; Helfat & Peteraf, 2009). Zollo and Winter (2002) present a learning model in which they establish
organizational learning as the source for the development and evolution of dynamic capabilities and operating routines. They argue that the emergence of organizational capabilities is based on the coevolution of three distinct, but interrelated learning mechanisms, namely experience accumulation, knowledge articulation, and knowledge codification.

While this unidirectional top-down learning perspective is generally accepted, the question arises whether lower-order operating routines may actually impact higher-order dynamic capabilities (Zahra et al., 2006). Although initial conceptual and empirical work points to the existence of such bottom-up learning processes between operating routines and dynamic capabilities (Ambrosini et al., 2009; Newey & Zahra, 2009), a coherent framing of this internal performance feedback loop does not yet exist. Nevertheless, the literature provides us with some starting points to begin our examination and to theorize about the nature of this internal performance feedback and its influence on bottom-up learning.

First, we know that dynamic capabilities do not produce value by themselves, but do so through the interaction with and adaptation of operating routines (Helfat et al., 2007; Zahra et al., 2006). This implies that information flows from operating routines back to dynamic capabilities. Second, Zollo and Winter (2002) argue that the development of capabilities depends on rather passive experiential learning as well as more deliberate investments in building them. Experiential learning processes such as learning-by-doing, trail-and-error learning, or improvisation support the adaptation to changing needs through the search for solutions to arising problems (Huber, 1991; Levitt & March, 1988). Existing theory is particularly supportive of experience-based learning as a driver of capability development and deployment (George, 2005). These inductive forms of learning require feedback on how well current capabilities perform (Teece & Pisano, 1994; Von Hippel & Tyre, 1995). In case of inaccurate or causally ambiguous feedback, organizations get caught in superstitious learning (Argote & Kane, 2003; Levitt & March, 1988). While these learning mechanisms reflect organizational level phenomena, we also need to look at the role of individuals in order to understand the development and evolution of organizational capabilities (Helfat & Peteraf, 2014; Teece, 2007). Third, learning from experience is challenging, as feedback may not be immediate enough or too causally ambiguous to be associated with a particular activity (Argote & Kane, 2003; Szulanski, 1996). As long as individuals are not aware of the performance implications of their actions, they will not benefit from their learning efforts (Argyris & Schön, 1978; Zollo & Winter, 2002). Indeed,
many contemporary quality management techniques build upon the mechanism of making these improvement activities and their outcomes visible (Cohen & Bacdayan, 1994). Furthermore, fast feedback produces psychological benefits as engineers feel more in control and are more willing to take risks (Reinertsen & Shaeffer, 2005), which is essential to innovation (Lounamaa & March, 1987). These findings underline the necessity of clear and timely performance feedback. Finally, it has been established that the development and deployment of dynamic capabilities depends, to a large extent, on the management’s perception of the need for change (Adner & Helfat, 2003). Managers start questioning the current way of doing things as soon as performance falls below their aspiration level (Greve, 2003). In other words, a lack of success and the recognition of failure with current operating routines increase the development and use of dynamic capabilities (McGrath, 1995). Thus, it is important to monitor and evaluate the performance of operating routines.

Although far from being exhaustive, this brief overview of the literature on the origin of organizational capabilities points to the missing bottom-up learning relationship in the current top-down learning model on the development of dynamic capabilities. We are addressing this gap in the existing literature by empirically showing that bottom-up learning, which is driven by internal feedback from lower-order operating routines, is an important complement to current models of capability development.

The LPD system as a dynamic capability

Before we present our research design and delve in the findings, we briefly motivate the classification of the LPD system as a dynamic capability. Building on Winter’s (2003) categorization of zero-, first-, and higher-order capabilities, we understand NPD as the zero-order capability. Since our study is conducted in the context of NPD in AutomationInc’s R&D department, the basic outputs are new products that are ready to be manufactured and sold. This stays in line with Winter’s argument that “for an independent R&D lab, developing new products is zero order activity” (2003:992). Likewise, Newey and Zahra view “the process of product development as a typical operating capability as it serves the firm’s current means of generating revenue and profit” (2009:S81). AutomationInc’s LPD system can thus be seen as a collection of routines that systematically monitor and modify the NPD process in pursuit of improved effectiveness and efficiency. To do so, the LPD system uses external inputs as well as internal feedback. Thus, it does not only function as an external sensing capability (Teece, 2007), but also an internal sensing capability.
Methodology

Research Design

In this paper, we aim at developing a better understanding of the nature and function of internal performance feedback loops and how they trigger the development of dynamic capabilities through a bottom-up learning process. Qualitative research designs are best suited to produce new theoretical insights (Burgelman, 1983; Miles & Huberman, 1994). Therefore, we have chosen an inductive, longitudinal single case study design to collect detailed evidence on our phenomenon (Eisenhardt & Graebner, 2007; Yin, 2009).

As previously mentioned, we studied the LPD system of AutomationInc, a mid-sized German high-tech company from the automation industry. It is one of the leading suppliers of industrial networking and factory automation solutions that include both hardware and software components. AutomationInc employs about 120 people in research and development. The case company is part of a larger US corporation (hereafter: CableCo) by which it was taken over in 2007. This is important as the US corporation has a strong lean orientation and required AutomationInc to join its lean journey. Thus, we have a rather precise date at which AutomationInc’s lean journey began. We got in touch with the company in the end of 2011 when AutomationInc was about to intensify its efforts to introduce lean management to new product development. Knowing that the firm already works with lean management techniques in manufacturing and that they were supported by CableCo, which had substantial experience in working with lean, although not in new product development, we decided to accompany this organization to study its lean implementation journey. By doing so, we have been able to gain unique, mostly real-time insights into the transformation of a typical NPD organization into an LPD organization. The study of AutomationInc’s LPD system thus provides unique insights into the development of dynamic capabilities.
Data collection

The case study was conducted by the first author of this paper. (We use the “I-form” to describe the fieldwork by the first author throughout the methodology section.) The data collection process can be divided into three major phases. The preparation phase started in December 2011 when I first met two representatives from AutomationInc, namely the present Director R&D and the present Project Management Officer (PMO). One of our colleagues invited them to participate in a workshop that was part of a larger research project on lean product development. That is when I learned about AutomationInc’s growing lean management activities in R&D. We invited them to participate in a second workshop in February 2012. These initial workshops were followed by a two-day on-site visit at the company in July 2012, when I conducted the first preliminary interviews for this study. Given that AutomationInc started its lean introduction journey in early 2011, the analysis of the first set of activities happened in retrospect by interviewing all key actors, who were involved in this early phase, and reviewing the documentation of these events. The preparation phase was followed by a four-month organizational ethnography-like field study between November 2012 and April 2013 (Van Maanen, 2011). During that time, I regularly visited the firm and spent about 45 days on site, which corresponds to about 2-3 days per week. I had the possibility to observe formal and informal meetings, which allowed me to draw a coherent picture of the organization’s lean management activities. A number of key events, e.g., the ‘Flow’ Kaizen workshop and the experimentation with and roll-out of the project review board, occurred during my observation period, which allowed me to gather firsthand information on the deployment of lean management in AutomationInc’s research and development department. The third phase, the follow-up phase, began in April 2013. We maintained the exchange with company representatives at workshops, conferences, and through regular phone calls. In November 2013, I visited the company for another round of interviews to discuss our interpretation of the events and to keep track of AutomationInc’s ongoing lean management activities.

The main source of evidence in this study is interview data. Between July 2012 and November 2013, I formally interviewed managers and engineers with various functional backgrounds from different hierarchical levels in order to examine the phenomenon from different perspectives. I first talked to those individuals that seemed to have the best knowledge of the phenomenon, namely those who were in charge of the development and deployment of the various lean management tools and techniques. The interviews with the
present and former Director R&D who is/was in charge of the overall implementation, as well as those of the present and former PMO who is/was responsible for the operational aspects of the implementation effort proved to be particularly insightful. In total, I conducted 25 interviews with 15 people (Table 1). Given the diverse background of my interview partners, I did not work with standardized interview guidelines. Following an ethnographic interviewing approach (Spradley, 1979), I mainly asked open questions to let the conversation flow and allowed my informants to freely recount their experiences during the lean introduction and to emphasize those events that they regarded as key (see also Rubin & Rubin, 2005). Whenever necessary, I interrupted and asked to the participants provide further information on specific issues. The interviews were audio taped and in most cases transcribed within 1-2 days.

Table 1: List of interview partners

<table>
<thead>
<tr>
<th>Relevant position</th>
<th>Hierarchical level</th>
<th>Time in relevant position (Years with AutomationInc)</th>
<th># of Formal Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Unit Manager</td>
<td>Top Management</td>
<td>04.2009-today (27y)</td>
<td>1</td>
</tr>
<tr>
<td>Present Director R&amp;D</td>
<td>Top Management</td>
<td>04.2012-today (21y)</td>
<td>3</td>
</tr>
<tr>
<td>Former Director R&amp;D</td>
<td>Top Management</td>
<td>04.2009-04.2012 (4y)</td>
<td>1</td>
</tr>
<tr>
<td>Present Project Management Officer (PMO)</td>
<td>Staff Level</td>
<td>10-2011-today (1.5y)</td>
<td>6</td>
</tr>
<tr>
<td>Former Project Management Officer (PMO), Lean Black Belt</td>
<td>Staff Level</td>
<td>04.2008-10.2011 (5y)</td>
<td>1</td>
</tr>
<tr>
<td>Lean Director 1</td>
<td>Corporate Function</td>
<td>07.2006-today (7y)</td>
<td>1</td>
</tr>
<tr>
<td>Lean Director 2</td>
<td>Corporate Function</td>
<td>06.2011-today* (7y)</td>
<td>1</td>
</tr>
<tr>
<td>Project Manager 1</td>
<td>Staff Level</td>
<td>2008-today (9y)</td>
<td>1</td>
</tr>
<tr>
<td>Project Manager 2</td>
<td>Staff Level</td>
<td>07.2012-today (&lt;1y)</td>
<td>1</td>
</tr>
<tr>
<td>Head of Product Management</td>
<td>Middle Management</td>
<td>2009-today (23y)</td>
<td>1</td>
</tr>
<tr>
<td>Head of Program Management</td>
<td>Middle Management</td>
<td>04.2012-today (23y)</td>
<td>2</td>
</tr>
<tr>
<td>Department Head Documentation, Lean Black Belt</td>
<td>Lower Management</td>
<td>01.2007-today (N/A) 01.2013-today</td>
<td>2</td>
</tr>
<tr>
<td>Department Head SW 1</td>
<td>Lower Management</td>
<td>2007-today (N/A)</td>
<td>1</td>
</tr>
<tr>
<td>Department Head SW 2</td>
<td>Lower Management</td>
<td>2010-today** (5y)</td>
<td>1</td>
</tr>
<tr>
<td>Department Head HW</td>
<td>Lower Management</td>
<td>10.2012-10.2013 (&lt;1y)</td>
<td>1</td>
</tr>
</tbody>
</table>

Total: 25

*Previous lean experience as lean site leader, **Previous lean experience as head of development in another BU
In addition to formally interview AutomationInc’s process management actors, I was able to observe them in formal meetings, focus group discussions, and workshops (Table 2). Furthermore, I received access to the firm’s intranet and internal Wikipedia system. The firm extensively documents its activities, therefore these systems proved to be an invaluable source of information. I could review lean training material, reports from the lean daily management meetings and 5-Why problem solving sessions, and information about past Kaizen events in R&D and other transactional process improvement (TPI) Kaizen workshops. We used this archival data to triangulate our evidence from the interviews and participant observations in order to increase the internal validity as well as the construct validity of our findings (Gibbert, Ruigrok, & Wicki, 2008; Mathison, 1988).

Table 2: Overview of the observed events

<table>
<thead>
<tr>
<th>Event</th>
<th>Frequency</th>
<th>(Average) duration</th>
<th>Number of observed events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean Daily Management</td>
<td>Weekly (Monday Afternoon)</td>
<td>20 minutes</td>
<td>7</td>
</tr>
<tr>
<td>Project Review</td>
<td>Weekly (Monday Afternoon)</td>
<td>20 minutes</td>
<td>7</td>
</tr>
<tr>
<td>Kaizen Event</td>
<td>On demand (in R&amp;D about every two years)</td>
<td>1 week</td>
<td>2</td>
</tr>
<tr>
<td>Kaizen Sustainment Board</td>
<td>Bi-weekly (Monday Afternoon)</td>
<td>5 minutes</td>
<td>1</td>
</tr>
<tr>
<td>5-Why Problem Solving Event</td>
<td>On demand</td>
<td>1 hour</td>
<td>1</td>
</tr>
<tr>
<td>5-Why Training Session</td>
<td>On demand</td>
<td>4 hours</td>
<td>1</td>
</tr>
<tr>
<td>Focus group discussions and external workshops with lean experts (LEAP events)</td>
<td>3-4 times a year</td>
<td>1-2 days</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total:</strong> 27</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data Analysis

Data analysis started immediately after the interviews by completing the notes and transcribing the audio files. Especially in the early phase of the fieldwork, I learned a lot from every interview I conducted and every event I observed. I used these insights to prepare for the next interview or observation. As soon as the amount of novelty decreased (Rubin & Rubin, 2005), I decided to stop data collection. I used the NVivo software package for qualitative data analysis to organize and handle the large amount of data that I collected. Following best practices for the analysis of case study evidence (Eisenhardt, 1989; Eisenhardt & Graebner, 2007), we iterated between empirical data, emerging
constructs, and the existing literature in the field to develop new theoretical understanding of the interactions between new product development and the LPD system. We applied a three-step data reduction and analysis procedure (as applied and described by Barley, Leonardi, & Bailey, 2012).

**First-Step: Understanding the tools**

Our unit of analysis is the LPD system. Overall, we identified 24 (lean) management tools that are somehow related to AutomationInc’s LPD system. In this study, we focus on those tools that are directly related to the monitoring of performance and subsequent resolution of problems (Table ). Building on the socio-materiality of organizational routines (Leonardi & Barley, 2010; Orlikowski, 2007), we clustered our data around these tools.

**Second-Step: Understanding the interactions and feedback loops**

To understand how performance feedback influences the development of dynamic capabilities, we need to know how information flows between different practices and tools. As we went through the data analysis process, we refined our coding scheme to focus on these interplays. The analysis shows that information flows through both technical and practice-based interfaces. Interestingly, many of the measurement, monitoring, and visualizing activities are still based on manual paper work.

**Third-Step: Understanding the coevolution**

In the third and final step, we merged the findings from the two first analysis steps. We linked the evolution of a single tool to the interactions between the tools. In doing so, we have been able to identify the triggers for the development and evolution of the tools and the system as a whole. That is when we found the development of dynamic capabilities, i.e., the LPD system is not only triggered by external stimuli, but even more so by internal performance feedback.

**Findings**

External stimuli are seen as the main trigger for the development of dynamic capabilities (Eisenhardt & Martin, 2000; Teece et al., 1997). This externally stimulated top-down learning process is important, especially in the early phases of dynamic capability development. In the later stages of capability development, however, bottom-up learning becomes increasingly important. In the following paragraphs, we describe
AutomationInc’s LPD system and illustrate how it developed over time. We then show how three distinct types of internal performance feedback inform the bottom-up learning process that drives the development of the LPD system.

Managing new product development

AutomationInc’s R&D management team introduced a number of lean management tools to NPD since 2009. Through this, they created a comprehensive LPD system that allows them to monitor and advance their product development activities. Table 3 briefly describes the tools that support these performance monitoring and problem solving tasks. Additionally, we list those (lean) management tools that are related to the LPD system and support it one way or another. Figure 1 illustrates the LPD system and demonstrates how it is embedded into AutomationInc’s R&D organization. The LPD system is the linchpin between the strategy formulation process that defines the corporation’s strategic direction and the everyday operational NPD activities. Before we detail the functioning of the LPD system with its performance monitoring and problems solving aspects, we briefly describe the surrounding elements.

Figure 1: AutomationInc's LPD system (for a description of the tools see Table 3)
Table 3: Management tools that are related to AutomationInc’s LPD system

<table>
<thead>
<tr>
<th>Management Tool</th>
<th>Label</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy Deployment Process</td>
<td>SDP</td>
<td>SDP is CableCo’s strategy formulation and deployment process. Following the principles of Hoshin Kanri, the organization's strategic goals are broken down and assigned to the top 4 management levels. The goals are formulated once a year and reviewed in a monthly meeting.</td>
</tr>
<tr>
<td>Lean Daily Management</td>
<td>LDM</td>
<td>LDM is a visual management tool that is used to monitor processes performance. The central element is a whiteboard on which process dependent KPIs are visualized and tracked. A weekly review meeting takes place in front of the board. LDM is deployed across different functions from manufacturing to new product development.</td>
</tr>
<tr>
<td>Team level Lean Daily Management</td>
<td>LDM*</td>
<td>Team level adaptation of lean daily management, which differs from the department level version in the definition of the KPIs.</td>
</tr>
<tr>
<td>Project Board Review</td>
<td>PBR</td>
<td>PBR is a visual management tool that is used to review the most important product and technology development projects. The central element is a large whiteboard on which project statuses are displayed. Weekly review meetings take place in front of the board.</td>
</tr>
<tr>
<td>Team level Project Board Review</td>
<td>PBR*</td>
<td>Team level adaptation of project board review. The team level version has been implemented in Promon in order to restrict the access to individual performance data.</td>
</tr>
<tr>
<td>Key Performance Indicator</td>
<td>KPI</td>
<td>KPIs are used in different tools (e.g. SDP, LDM, etc.) to measure and calculate process performance.</td>
</tr>
<tr>
<td>Project Data Management System</td>
<td>Promon</td>
<td>Promon is an IT-based project management tool that provides a visual interface to further databases, such as MS Project and the bug-tracking database.</td>
</tr>
<tr>
<td>Kaizen Workshop</td>
<td>Kaizen</td>
<td>Kaizen Workshops are extensive cross-functional process improvement workshops. These week-long workshops are typically attended by 10-15 people. Several types of Kaizens have been developed. In research and development, Value Stream Mapping (VSM) and Transactional Process Improvement (TPI) are most commonly deployed.</td>
</tr>
<tr>
<td>Kaizen Sustainment Board</td>
<td>KSB</td>
<td>The Kaizen Sustainment Board is used to track the results and countermeasures of Kaizen workshops.</td>
</tr>
<tr>
<td>Issue Board</td>
<td>IB</td>
<td>The Issue Board is used to track the results of various problem solving and process improvement activities that have not been conducted in relation to LDM or a specific Kaizen workshop.</td>
</tr>
<tr>
<td>5-Why Problem Solving</td>
<td>5-Why</td>
<td>5-Why is a highly standardized problem solving process that is promoted throughout CableCo. Central to the process is an in-depth root cause analysis by asking five times why. Oftentimes quick fixes are implemented to keep the production or development running while the solution to the root cause might take additional time.</td>
</tr>
<tr>
<td>Portfolio Planning</td>
<td>-</td>
<td>Quarter-yearly road mapping process to select and schedule the products and technologies that are to be developed.</td>
</tr>
</tbody>
</table>

**Strategy formulation**

AutomationInc’s lean journey started with the introduction of CableCo’s ‘Hoshin Kanri’ strategy deployment process (SDP) towards the end of 2008. In the course of the annual strategy formulation, the overall goals of the firm are broken down and assigned to the top four management levels. At these levels, the achievement of the goals is related to the annual performance appraisal and is, therefore, bonus relevant. The given objectives are
then translated into Key Performance Indicators (KPIs) that are tracked with the lean daily management (LDM) tool. Although SDP is not a typical lean management tool, it is regarded as the backbone of the lean organization.

**New product development**

AutomationInc’s R&D department ensures a constant flow of new and innovative products to better serve existing customers and to acquire new ones. Therefore they permanently work on about 30 projects in different stages. Most of these projects are related to the development part rather than on the research part of R&D as AutomationInc conducts only a few pure technology development projects. They typically develop new technologies in the context of a specific product development project. As the development of new technologies is uncertain and might jeopardize project planning, this can be risky. In order to deal with these uncertainties, the organization established an extensive monitoring system that allows them to immediately identify emerging problems.

**Problem solving**

The monitoring of performance with LDM, PBR, and the other tools is only useful if an organization has effective problem solving and process improvement routines in place to resolve the emerging issues. The problem solving aspect of the LPD system is dedicated to the solution of technical and administrative problems. For smaller problem solving efforts, they apply the highly standardized problem solving routine, which they refer to as ‘5-Why’. For larger process improvement projects, they use the Kaizen workshop format.

**Performance monitoring**

By the end of 2013, when our observation period ended, AutomationInc had installed step-by-step a comprehensive performance monitoring system. LDM and PBR are the most central tools for the measurement and evaluation of new product development performance. While LDM visualizes the average performance of the NPD process, PBR displays problems with specific development projects or functional departments. We present these two tools in more detail as we describe the nature and functioning of the three bottom-up feedback loops in the following paragraphs.
Dynamics of the LPD system development

The development of AutomationInc’s LPD system was not a steady process. Figure 2 illustrates how the LPD system was formed through the step-by-step introduction of several lean management tools over the course of five years. The introduction of lean management was triggered by CableCo and required AutomationInc to become lean in all its organizational domains. This was a strong signal for the adoption of lean management. However, in R&D relatively little has happened during the first 3 years. It was not until early 2012 that the lean transformation gained momentum. Why was it that the initiative advanced so slowly in the beginning? And why did it eventually gain so much momentum? Our evidence indicates that the development of the LPD system is driven by the interplay of three distinct internal performance feedback loops: First, there is the awareness of lean management by the NPD actors. The second type of feedback is the successful identification and solution of technical and administrative NPD problems through the LPD system. Third, there is the codification and visualization of NPD performance through the LPD system. Together, these feedback processes trigger directly or indirectly a bottom-up learning process that drives the development of the LPD system. In the next paragraphs, we describe these three bottom-up learning processes and show how their nature and function changed over time.

Figure 2: The dynamics of the LPD system development
Lean awareness

Involvement fosters awareness. Being aware of the existence and, more importantly, of the benefits that the lean management provides is a necessary prerequisite for the advancement of the LPD system. Employees must therefore be actively involved in the lean transformation efforts. Figure 3 illustrates when the different hierarchical levels started to participate in lean management activities.

*Top Management:* In the beginning, the top management got involved through various activities such as lean boot camps, the advanced lean leadership program, or the introduction of SDP. Similarly, the first Kaizen workshop, the V-Model Kaizen, was mainly a top management activity and since it was organized with another business unit, only five managers from AutomationInc’s R&D department were able to participate. Consequently, only a few (top) managers were involved in the lean management activities during the first one and a half years of the lean transformation. In this early phase, the activities were almost exclusively triggered by CableCo’s top management and its lean experts.

*Middle Management:* The group of active participants increased with the introduction of LDM and the implementation of the PDVSM Kaizen workshop. The introduction of LDM has been the first key event in the development of the LPD system. As all the department heads are required to participate in the weekly LDM meeting, the middle management layer got involved in regular lean management activities. Moreover, the second Kaizen was independently organized and conducted by the R&D department. The present Director R&D and former PMO organized the workshop and the Department Head Documentation moderated it. In this way, they were able to involve more people from R&D.

“If I want to change something, I need to involve and enthuse a larger number of people. People are very hard to inspire in retrospect and therefore one needs to involve a critical number of people upfront.” (Present Director R&D)

These two events have been initiated by AutomationInc’s R&D management to comply with CableCo’s lean transformation. In that sense, there still exists a strong external stimulus. The initiative for and definition of activities, however, was driven bottom-up.
Team level: Through the installation of Obeya project management rooms, the experimentation with SBCE, and the conduct of two 5-Why training sessions, an even larger group of people has been included in lean management related activities during 2012. For the first time, project managers and team level employees became actively involved. The second key event after the introduction of LDM is the introduction of PBR. After a short, highly successful experimentation stage with a small pilot board, PBR was fully rolled out in the beginning of 2013. The tool proved extremely valuable for the project managers and the department heads as it allows them to coordinate their development activities much more effectively. Despite the increasing number of activities, the impact of lean at the team level was still vague:

“I think that lean did not yet arrive at the team level. (...) I think that it just arrived at the project management level. Down to this level, it is understood and more or less implemented.” (Department Head SW 1; early 2013)

The Department Head Documentation introduced the first team level LDM board in the beginning of 2013. Shortly after, two more department heads followed his example and introduced their own team-level LDM board towards the end of 2013. Because of their success, team level LDM boards were made mandatory for every department. The definition of an adequate set of KPIs was left to the department heads. Most made this a team activity in order to increase the support for the tool.

The experimentation with Obeya and SBCE, the realization of 5-Why training sessions, and the introduction of PBR have all been initiated by the R&D management. Given the success they had with the LDM, they started to understand the value of lean management and the benefits that the application of the corresponding tools and techniques has on NPD performance. Likewise, the introduction of the team-level LDM board was proactively driven bottom-up by the Department Head Documentation, who designed and introduced an LDM board for his team. With the introduction of these team level LDM boards, the LPD system eventually penetrated the whole R&D department. Moreover, it is no longer CableCo that influences AutomationInc’s R&D management team, but rather CableCo asks them to help with the introduction of lean in other parts of the organization.
Problems as indicator of NPD performance

The identification and solution of problems is an integral part of new product development (e.g. Brown & Eisenhardt, 1997). Although most problems in R&D are technical in nature, they also point to faulty processes and procedures (Hackman & Wageman, 1995) and are, therefore, an important source for organizational change (Sitkin, 1992). AutomationInc’s LPD system supports the identification and resolution of problems in multiple ways. First, product issues that have been identified by customers appear on the lean daily management (LDM) board so that the top and middle management is informed about the most critical issues on a weekly basis and can begin the necessary countermeasures. Second, problems that occur in the development projects are reported to the R&D management team through the PBR board. Together with the project managers, the top and middle management get a comprehensive overview on the current state of the NPD process.

Project board review: PBR is a visual management tool that provides an overview of how the most important product and technology development projects perform. The central tool and name-giving element is a large magnetic whiteboard in front of which the weekly review meeting takes place. The projects are listed on the horizontal axis of the board and the different R&D functions on the vertical axis. Prior to the meeting, the department heads update the current status of their function with regard to each project by putting a colored magnet on the intersection. A white magnet indicates that the function is currently not...
involved in the project. Green means that the work is progressing as expected. Yellow indicates problems have been identified, but that they are under control. And red means that unresolved issues still exist. Project managers do the same from a project perspective. Collecting feedback from people with different perspectives on the project status creates a good deal of transparency within and across projects. Whenever a red magnet needs to be placed, the responsible manager has to report what the problem is and which countermeasures have been defined. They do so by answering three questions: 1) What is the problem? 2) What is the solution to the problem? 3) From whom do you need support to solve the problem? That means that whoever has to report a problem needs to be prepared for the meeting and already have a potential solution ready. Given that the whole R&D management team attends this meeting, decisions such as the prioritization of projects or the reallocation of resources can be taken quickly and unbureaucratically.

“Before all, PBR is a communication tool. [It is about] communication, visualization and the creation of transparency. Everyone who is involved in a project, or is by mistake not involved, is present and can see all project [statuses]. One can see how many projects are on track and with which we face difficulties.” (Present Project Management Officer)

“Let’s put it like this, given that problems are visible and being talked about [during the review meeting] one looks for solutions more immediately. The expectation is that if someone puts a red dot on the board that he or she proposes a solution, or asks for specific support. Just saying that the project is red does not work anymore.” (Department Head Documentation)

As important as the timely detection of problems is the reliable resolution of them. AutomationInc introduced a standardized 5-Why problem solving process that ensures the proper identification of the underlying cause. However, it was difficult to convince the managers and engineers of the benefits of the 5-Why routine.

“We [the management team] already work with 5-Why for some years and we also went through a learning process. (...) It took us almost two years to actually recognize the benefits stemming from continually working on this topic. And it took quite an effort by our Business Unit Manager to anchor that in people’s minds.” (Present Director R&D)
“It took a while (...) until [standardized problem solving] diffused into the organization, until the people realized that this makes sense, and until they started to that voluntarily in their projects. It took two to three years until they saw the real benefit.” (Present Project Management Officer)

Upon the occurrence of technical problems, the short-term goal is to solve them as soon as possible. This oftentimes involves quick fixes, which ensure that development can proceed or that the customer can continue using the product. More important than these quick fixes, however, are the long-term implications of these technical problem-solving efforts. The aim is to prevent these problems from occurring again, and this often necessitates the adaptation of existing templates, checklists, or processes. Similarly, when a function must regularly place red buttons on the PBR board, this alludes to the existence of more serious problems. Given that problems are highly visible, it is more difficult to ignore them and, therefore, management is urged to resolve them in a timely matter. Looking at the timeline, the tools that help to identify problems, i.e., PBR, and to properly solve them, i.e., 5-Why, have not been introduced or trained before 2012. This does not imply that AutomationInc would have performed poorly beforehand, but the identification of problems took much longer and their resolution did not always result in permanent NPD process improvements. The increasingly successful identification and solution of problems raised awareness of the benefits of the LPD system and has, thus, indirectly become an important driving force for its further development.

**Key performance indicators as proxies for NPD performance**

Lean daily management measures and visualizes NPD performance with a set of KPIs that follow the S-Q-D-C-I logic that builds on to the ‘iron triangle’ of cost, time, and quality (Atkinson, 1999). For which ever process an LDM board is set up, the management has to define KPIs that provide feedback on Safety, Quality, Delivery, Cost, and Inventory aspects. In R&D, the Quality- and the Safety-KPI point at specific problems while the other KPIs represent an average value of NPD performance. The usefulness of lean daily management greatly depends on the quality of these KPIs and how well they represent the underlying process. The current values are reported and manually updated during the weekly LDM review meeting. Given that most of the performance data is electronically available, it would be possible to build a digital LDM board using a big (touch) screen. However, CableCo’s lean experts insist on using pen and paper for the reporting. They argue that manually drawing a red KPI in front of the other meeting participants creates a
stronger personal involvement and a higher commitment for the solution of emerging problems.

Finding the right set of KPIs to measure NPD performance was challenging and caused some difficulties. Unlike the manufacturing context, processes in R&D are hardly visible and much less tangible. In order to define the first set of LDM KPIs, AutomationInc built upon CableCo’s LDM templates and asked for support from its lean experts. Since CableCo’s lean experts had a manufacturing background, the collaboration on the definition of these KPIs was not without difficulty.

“This really was a problem. [The lean director] who supported us with the introduction of the lean daily management board, was having a production and supply chain management perspective and had nothing to do with product development. Thus we had a hard time choosing the right key performance indicators.” (Former Project Management Officer)

Consequently, the first set of KPIs was only partially useful and most were adapted or replaced over time (Figure 4). The adaptation of the KPIs is an ongoing learning process. Learning about the usefulness of the KPIs is, at least in part, a learning-by-doing process. The first Inventory-KPI, for example, measured the average duration of the projects that are currently between gate 3 and gate 5. While this is an interesting value, it was of limited use for the actual planning of the available development capacity. Hence, the Inventory2-KPI and its refinement, the Inventroy3-KPI, measure the load factor of the department over the coming two weeks, which allows for an active capacity management. The adaptation of the Cost1-KPI, on the other hand, was the result of a 5-Why analysis that had been performed because the values were not replicable. As it turned out, the reason was not a formula that was wrong, but the buggy data exchange between two software packages.
More important than the direct impact of LDM on the evolution of the NPD processes is the indirect impact on the development of the LPD system. With the ongoing adaptation, the value of the LDM board has increased and the participating managers started to recognize the benefits of visualizing performance. Having permanent, visual feedback on the current performance increases the awareness for existing potential for improvement.

The positive experiences with LDM lead to the integration and development of further monitoring tools, such as the team-level LDM, the PBR, and also the kaizen sustainment board (KSB) and the issue board (IB). With the development of the LPD system, AutomationInc managed to close the gap between strategy-making and everyday product development. While the KPIs that are used on the top management level are abstract and, therefore not directly relevant for an engineer at the lowest hierarchical level, the downward cascading of KPIs ensures that everyone can relate their activities to the overall strategic goal of the organization.

So far we have identified and described three distinct types of internal performance feedback, namely lean awareness, problem identification, and solution and key performance indicators. Table 4 summarizes and characterizes the different types of feedback. In the next section, we will show how these feedback loops relate to one another and drive the development of the LPD system through bottom-up learning.
Table 4: Types of internal bottom-up feedback that trigger the development of the LPD system

<table>
<thead>
<tr>
<th>Scope</th>
<th>Scope</th>
<th>Direction</th>
<th>Frequency</th>
<th>Memory function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean awareness</td>
<td>holistic</td>
<td>Top-down → bottom up (direct)</td>
<td>continuous</td>
<td>Individual</td>
</tr>
<tr>
<td>Problems as indicator of NPD performance</td>
<td>specific, punctuated</td>
<td>Bottom-up (indirect)</td>
<td>ad-hoc → weekly (PBR)</td>
<td>NPD process (hidden, unless actively retrieved)</td>
</tr>
<tr>
<td>Key performance indicators as proxies for NPD performance</td>
<td>holistic, averaged</td>
<td>Bottom-up (direct, indirect)</td>
<td>weekly (LDM) monthly (SDP)</td>
<td>LPD system (visualized on boards and screens)</td>
</tr>
</tbody>
</table>

**Discussion**

As we have seen, the development of AutomationInc’s LPD system was not a steady process (Figure 2). In fact, relatively little happened during the first 3 years of the lean transformation, and it was not before late 2012 that the development of the LPDs system gained momentum. We argue that the dynamics of this developmental path can be partially attributed to a bottom-up learning process that is influenced by three distinct types of internal performance feedback. This is in part because this bottom-up learning process does not replace, but rather complements the top down learning models that are driven by external stimuli (Teece, 2007; Teece et al., 1997). By showing the nature and successful function of this internal feedback loop, we extend upon recent work that indicates the existence of such a bottom-up learning process (Newey & Zahra, 2009; Zahra et al., 2006). Figure 5 illustrates how the three feedback processes relate to each other and directly or indirectly influence the development of the LPD system. Table 5 shows a number of examples that illustrate the feedback processes. In the following paragraphs, we briefly discuss these direct and indirect moderating relationships.
Direct impact of lean awareness on the development of the LPD system (P1)

Being aware of lean means knowing about the benefits that the various lean management tools and techniques can provide. This is best achieved by directly involving the organizational actors so that they can learn about these benefits from their own firsthand experience. As we know, learning from direct experience is much more powerful than learning from the experience of others (Argote & Greve, 2007; Argote & Miron-Spektor, 2011). If the participants in newly established meetings or reporting structures do not see any benefits, these practices are perceived as coercive rather than enabling formalization (Adler & Borys, 1996). Adler and Borys argue that “enabling procedures help committed employees do their jobs more effectively and reinforce their commitment” (1996:84). When AutomationInc’s R&D learned about the benefits of the LPD system, their commitment increased and they started to introduce additional tools (from LDM to PBR, from LDM at the department level to LDM at the team level, etc…). However, dynamic capabilities do not produce value in themselves, but only through the operating routines that they act upon (Helfat et al., 2007). The LPD system is only a means to an end, and the primary goal is to develop products more effectively and efficiently. The balance between doing too little with no benefit and doing too much is a fine line.
<table>
<thead>
<tr>
<th>Trigger</th>
<th>Tool</th>
<th>Short-term implication</th>
<th>Long-term implication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing capacity shortages at the SW testing group (Team-level initiative)</td>
<td>NPD process (PBR)</td>
<td>-</td>
<td>Increasing automation of SW testing</td>
</tr>
<tr>
<td>Lack of transparency between the development project complicated resource planning and allocation</td>
<td>NPD process</td>
<td>-</td>
<td>Introduction of PBR</td>
</tr>
<tr>
<td>Memory function for PBR is needed, so that important issues are not forgotten. (Learning-by-doing) (PMO Initiative)</td>
<td>PBR</td>
<td>-</td>
<td>Extending the PBR board with a burning platform</td>
</tr>
<tr>
<td>Kaizen newspapers have been ignored. (Middle Management Initiative)</td>
<td>KBS in operations</td>
<td>-</td>
<td>Setting up of the Kaizen Sustainmen Board</td>
</tr>
<tr>
<td>5-Why tracking has been ignored. (PMO Initiative)</td>
<td>-</td>
<td>-</td>
<td>Setting up the Issue Board</td>
</tr>
<tr>
<td>Software bug has been reported by a customer. The resolution of the bug lead to a more serious security issue, because the subsequent testing was not extensive enough.</td>
<td>LDM (Q-KPI)</td>
<td>Solving of problems</td>
<td>5-Why analysis → Adjustment of checklist</td>
</tr>
<tr>
<td>Mile stone has been missed, because of delayed testing activities.</td>
<td>NPD process</td>
<td>Postponing milestone</td>
<td>Creating checklist Adjustment of responsibilities</td>
</tr>
<tr>
<td>PBR is supporting the identification and solution of product- and project-related problems, which is leads to a positive awareness of lean management</td>
<td>PBR (NPD process)</td>
<td>-</td>
<td>Adaptation of PBR to the team-level</td>
</tr>
<tr>
<td>Adaptation of LDM KPIs in response to increased NPD performance</td>
<td>LDM</td>
<td>-</td>
<td>Adjustment of LDM S-KPI and Cl-KPI</td>
</tr>
<tr>
<td>Adaptation of LDM KPIs in response to Kaizen workshop Existing KPIs</td>
<td>LDM</td>
<td>-</td>
<td>Adjustment of LDM D-KPI and 11-KPI</td>
</tr>
<tr>
<td>Adaptation of LDM KPIs in response to inadequate definition.</td>
<td>LDM</td>
<td>-</td>
<td>Adjustment of LDM 12-KPI</td>
</tr>
<tr>
<td>Transfer of LDM to the team level (Middle Management Initiative)</td>
<td>LDM</td>
<td>-</td>
<td>Adaptation of LDM to the team level</td>
</tr>
</tbody>
</table>
Indirect impact of problem-solving on the development of the LPD system (P2)

Technical and administrative problems that occur during development also hint at problems with the underlying processes and procedures (Hackman & Wageman, 1995; Sitkin, 1992). The solution of these technical problems often leads directly to small improvements of the NPD process in the form of adjusted checklists or redefined process steps. Such learning from problem-solving is an important driver of organizational change (Tucker, Edmondson, & Spear, 2002) and relates to the rather passive process of experience accumulation that leads to an optimization of the existing routines (Zahra et al., 2006; Zollo & Winter, 2002). However, the identification and solution of problems does not only have a direct impact on the NPD process, but also an indirect one on the development of the LDP system (P2). The project board review meeting, which is the main tool for problem detection, turned into a huge success. The participating department heads and project managers greatly benefit from the tool, which further creates positive associations with the LPD system as a whole. In this case, the organizations quickly perceived the additional meeting as enabling rather than seeing it as coercive formalization (Adler & Borys, 1996). This is best shown by the fact that one department head copied the PBR logic and created a similar feedback mechanism for his own team. Yet, the effect of successfully identifying and solving problems on the development of the LPD system remains mainly indirect as it typically increases the awareness of the benefits of lean.

Indirect impact of performance measurement on the development of the LPD system (P3)

Ambrosini et al. (2009) argue that the need for change depends on the awareness and understanding of the perception of performance and personal motivations (see also Greve, 2003; Zollo & Winter, 2002). Visualizing performance metrics is a powerful incentive mechanism. Although the effect is not as immediate as with PBR, where an individual has to place green or red magnets, the LDM KPIs provide a feedback on whether the organization, i.e., the R&D department as a whole, is on the right track. And this is what makes up most of what is being evaluated and rewarded by the top management. Improving KPIs on the LDM board thus reinforces the commitment for the lean transformation and justifies further investments in these activities.
Direct impact of performance measurement on the development of the LPD system (P4)

The direct impact of performance measurement is obvious in the sense that the very purpose of LDM is the measurement and visualization of NPD performance. This implies that performance changes at the level of the NPD process, i.e., the operating routines that require an adaptation of LDM, i.e. the dynamic capabilities, are readily visible. Indeed, as the performance of the NPD process has improved, the KPIs turned green and have stayed green. Consequently, they did not trigger any further improvements. The challenge is then to define KPIs and set aspiration levels that are challenging, but remain achievable (Cyert & March, 1963; Greve, 2003). If they are too challenging and the performance indicators remain below the aspiration level, employees might get frustrated. In both cases, over- or underperformance with regard to the chosen measures, LDM itself indicates a necessary adaptation or reconfiguration of the KPIs in order to maintain its usefulness. Therefore, the performance measurement also has a direct impact on the LPD system.

In summary, the various LPD tools provide different types of feedback about the performance of the NPD processes, which reinforces the commitment to the lean transformation. Taken together, the three distinct but interrelated types of feedback might explain a great deal of the dynamics that we observed during the development of the LPD system. The more tools that have been introduced and the more actors that have been involved, the faster the system has developed (Figure 2). Figure 6 shows a simplified, schematic representation of the three internal feedback loops and how they add up. We simply laid one feedback process on top of the other, starting from the time that each mechanism has been installed. Although this representation is only based on anecdotal evidence and provides cues rather than exact evidence, the dynamics of the development of the LPD system correlate with the increasing amount of bottom-up feedback available. Hence, we argue that bottom-up learning from lower-order operating routines is an important learning mechanism in explaining the development of dynamic capabilities. Therefore, we suggest complementing externally stimulated top-down learning models with an internally triggered bottom-up learning process.
Implications for practice

Our research highlights the benefits of building a performance monitoring system that ensures the timely capturing and evaluation of process performance data. However, measuring performance and, in particular, the performance of dynamic capabilities is challenging (Helfat et al., 2007). In this paper, we outlined the structure of a comprehensive LPD system and detailed the processes that evolve around the different tools and techniques. Managers can build on these insights to develop their firm’s performance monitoring system. The challenge, however, is to find KPIs that accurately represent how the company functions.

*A book can provide suggestions for key performance indicators. However, a book cannot tell you whether they really match your industry, your firm, or your strategy. (Present Project Management Officer)*

Furthermore, managers need to recognize that internal performance feedback is only useful if they can instantaneously respond to the weaknesses that have been identified. Hence, they need to invest in process improvement and problem-solving capabilities along with
the development of the performance monitoring system. If they manage to do so, learning from internal performance feedback is a valuable complement to externally stimulated strategy-making processes.

Yet, the introduction of such an extensive LPD system is a lengthy trial and error learning process. It takes time until the value of the different tools becomes visible. Other tools may not work and are thus rejected, for example AutomationInc’s Obeya rooms. Experience has shown, however, that persistence pays off in the long-term.

**Limitations and future research**

Admittedly, our research suffers from some limitations. Our analysis is based on an inductive, longitudinal case study of a single firm that allows us to analyze the development of the AutomationInc’s LPD system in such great depth (Siggelkow, 2007). While a case study design allows for building new theory, the findings can often not be generalized (Eisenhardt, 1989; Gibbert et al., 2008). We can partially adjust for this as we build on evidence from the introduction of several tools that allow us to draw a more precise picture of the bottom-up learning processes and the dynamics of capability development. However, further cases would be needed to replicate our findings. In particular, negative cases might be useful in challenging our findings. As is apparent, our case company turned out to be very successful. With the same number of people, AutomationInc’s R&D organization is now able to handle considerably more development projects. The fact that the team was successful most certainly has an influence on the learning process. What is more, we can elaborate on the processes through which the organization captures and evaluates performance feedback, but we cannot entirely separate the procedural from the human aspects. Ideally, we would have data from additional companies with similar performance monitoring systems, but different management teams, in order to compare and contrast our findings. Yet, building theory from case studies is an excellent means in bridging rich qualitative evidence to mainstream deductive research (Eisenhardt & Graebner, 2007). Our model thus provides a starting point for further confirmatory research. As we rely mainly on anecdotal evidence, future research could try to quantify the three different types of performance feedback to confirm the dynamics of dynamic capability development.
Conclusion

In this paper, we examine the development of dynamic capabilities in response to bottom-up learning processes that are driven by internal performance feedback. In particular, we analyze the development of AutomationInc’s LPD system through which it monitors its NPD process in order to identify problems and weaknesses in a timely manner. We identify three distinct sources of NPD performance feedback, namely lean awareness, problem identification and solving, and key performance indicators. This feedback triggers either direct or indirect bottom-up learning that drives the evolution of the organization’s NPD routines and the development of the LPD system. Therefore, we suggest having a traditional top-down learning models of capability development to complement a bottom-up learning process.

References


10.3 Paper 3 - The future of organizational learning research: A conversation with Professor Linda Argote

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Printed version: Second-draft of the manuscript as submitted to the editor
Recent advancements in technology and the future of organizational learning research: A conversation with Professor Linda Argote

Sunkee Lee (INSEAD)
Florian Rittiner (ETH Zurich)
Gabriel Szulanski (INSEAD)

Introduction

This essay builds on an interview with Professor Linda Argote (Carnegie Melon University), an influential thinker in the organizational learning field. The interview was conducted by two PhD students, Sunkee Lee (INSEAD) and Florian Rittiner (ETH Zurich) during the 2013 Strategic Management Society (SMS) Conference. The conversation with Linda was one of a series of interviews with foundational scholars in strategy and organizational studies initiated by the Knowledge and Innovation Interest Group of the Strategic Management Society in 2011.

This essay elaborates on remarks made by Professor Argote on how recent developments in technology might change the research on organizational learning. On the one hand, advancements in technologies enable researchers to examine learning mechanisms at a finer level. Tools that are borrowed from neuroscience, as for example fMRI (functional magnetic resonance imaging), allow for the tracking of neuronal activity in order to localize and examine learning processes within the human brain. On the other hand, advancements in information and communication technology (ICT) have enabled new forms of organizations in which members are no longer geographically and physically co-located. This changes how people communicate and collaborate, and makes it necessary to re-think existing concepts and theories of organizational learning. In this essay, we review these two technological developments to provide a context for Professor Argote’s remarks which suggest ways they might influence the research in organizational learning.
Neuroscience and organizational learning – from a micro to a neuronal level of analysis

In recent years, the strategy field has increasingly focused on understanding the “microfoundations” (Barney & Felin, 2013; Coff & Kryscynski, 2011; Felin & Foss, 2009; Powell, 2011; Powell, Lovallo, & Fox, 2011), a quest to identify micro level drivers of macro level outcomes. A similar interest has developed within the field of organizational learning (Gavetti, 2005, 2012; Gavetti, Greve, Levinthal, & Ocasio, 2012; Greve, 2013). Accordingly, this movement led for example to an increased appetite in the strategy field for traditional micro-level research designs, such as experimental studies (i.e. Bardolet, Fox, & Lovallo, 2011; Ederer & Manso, 2013). The field has now reached a state in which techniques from neuroscience are borrowed in order to study fundamental mechanisms underlying learning and strategy making processes, such as the exploration vs. exploitation decisions by managers (see also Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2014). Linda’s comment alludes to these developments, especially those which stimulated her own research:

“I think the studies in cognitive neuroscience have the potential to say something about the mechanisms behind the learning. So for example I got involved in a project with a group in Denmark. I was hoping we could understand the difference between the mindful and less mindful processing. There's a fair amount of evidence in the individual psychology. They know where that's happening at the individual level... it's a frontal cortex sort of area... and I thought... well that... we invoked this concept of mindful and mind... well we don't want to say mindless, nobody can get mindless [Laugh] but, less mindful learning, and it would be fascinating if we could validate that and get at the underlying mechanism.” (Linda Argote, Interview)

Neuroscience provides useful tools to researchers who study learning processes. Adopting neuroscience tools is said to have two major advantages for testing theory compared to conventional approaches (Volk & Köhler, 2012). First, neuroscience techniques can reveal the functioning of the brain while participants engage in tasks in a controlled experimental setting. This allows the researcher to pin-point the neural functioning during a learning process, and hence aids the further investigation of learning mechanisms. For example, Senior, Lee, and Butler (2011) note that individuals encode social and nonsocial information in their neural system differently despite the surface-level similarity between the two types of information. The encoding of social information for future retrieval is
related to activity in the dorsomedial prefrontal cortex, while such process for nonsocial information is related to activity in the hippocampus. This could have implications for studying transactive memory systems (TMS), as TMS involve not only retrieving knowledge that a focal individual possesses (nonsocial information) but also remembering and utilizing knowledge that the individual’s peers possess (social information) (Liang, Moreland, & Argote, 1995; Wegner, 1987). Other well-known concepts of the organizational learning literature such as declarative knowledge vs. procedural knowledge (e.g. Cohen & Bacdayan, 1994; Singley, 1989), deliberate learning (Zollo & Singh, 2004; Zollo & Winter, 2002), and vicarious learning (e.g. Bandura & McClelland, 1977; Denrell, 2003; Kim & Miner, 2007) could also be further developed using tools from neuroscience.

The second related advantage of neuroscience tools for testing theory is that it helps testing competing theories against each other to eliminate inaccurate or ill-fitting theories (Powell, 2011; Volk & Köhler, 2012). For instance, Linda explained in the interview:

“One of the things that we've tried to look at is, and this is actually in a laboratory study, is the role of identity, which we think is very important... That if you share an identity with someone you're more likely to give them a chance to try to learn from them. Whereas if you don't share an identity, you're more likely to reject it, and that's not the way we do things here. So I'm not saying a blind adoption... That if you share an identity with someone, you'll do whatever they say, but more that you'll give them a chance to show what they know and see if you can learn with them. So I think the whole issue of identity is fascinating.” (Linda Argote, Interview)

While the concept of “identity sharing” theorizes on whether individuals decide to learn from their peers or not, the reluctance of learning can be attributed to either a cognitive response or an emotional response. Both arguments are plausible, but the mechanisms behind them originate from significantly different psychological processes. With the help of an fMRI scan, these two competing arguments can be tested by examining which part of the brain shows more activity. When the researcher observes a change of activity in the prefrontal cortex, it is more likely a cognitive response; if the change occurs in the limbic system, it is more probably an emotional response, (Dalgleish, 2004; E. K. Miller & Cohen, 2001; Volk & Köhler, 2012). Neuroscience tools will help to alleviate the issue of
“strategy theories using unobserved psychological constructs to explain observed behavior” (Powell, 2011: 1485).

In spite of these advantages of adopting neuroscience techniques to research on organizational learning, Linda also referred to some shortcomings:

“You can study one person (with neuroscience techniques), and there have been a few attempts to link two people but you know, studying groups or studying organizations (might be different and difficult)... I understand somebody is working on developing FMRI that are more like caps that you can just put on instead of having to go into these machines, so maybe that will be on the horizon, but... my point is, I think it's certainly not going to replace the kind of field work we're doing. I think the combination may help us say something about the underlying mechanisms or may help us validate measures, if we can get pencil and paper measures and then validate it with a brain scan measure...maybe that will give us greater faith in... the findings but I don't think it's going to substitute for field work, and because of lot of what we do is about larger aggregates than the individuals, and that's often where the, you know, exciting action is, I want us to keep our focus on that, and not forget the fact that we're, you know... organizations are multiple people, they're not just one.”

As Linda points out, these neuroscience tools have their limits when a group or an organization is to be studied. Nonetheless, Volk & Köhler (2012) show that recent developments in technology may help researchers to overcome these limitations. For example, hyperscanning makes the simultaneous fMRI scanning of multiple individuals that are all engaged in the identical task possible (e.g. Montague et al., 2002). What is more, portable neuroscience methods such as wireless EEG systems (e.g., Berka et al., 2004) or wearable NIRS systems (e.g. Hoshi, 2005) allows individuals to move around or physically interact with their group members during the test. These developments are very important, because group-level or organizational-level learning dynamics are different from that of individual learning as the social processes are involved (Senior et al., 2011). Future studies will be able to study concepts such as transactive memory systems due to this development.
ICT and organizational learning – from a capture to a connect model

Information and communication technology has long been recognized as important enabler of organizational learning (Argyris, 1977). Nevertheless, the research on how ICT influences organizational learning is still in its infancy (Argote & Miron-Spektor, 2011; Dodgson, Gann, & Phillips, 2013). Yet, organizations make significant investments in information technology to support their knowledge management practices (Choi, Lee, & Yoo, 2010). They further follow different approaches when selecting and introducing tools to facilitate the creation, transfer, storage and application of organizational knowledge (Alavi & Leidner, 2001; Marwick, 2001). In our interview, Linda distinguished between the capture model and the connect model and outlined how recent developments in technology suggest a shift towards the latter:

“So I think that whole issue of technology and what role does it play in learning... my sense of the knowledge management systems seemed to be shifting from the capture model, the building of the repositories, to more of a connect model, to try to have opportunities where people can ask questions or respond that way, and then can maybe follow up with a person offline. But I think that's a very rich area for us to learn more about.” (Linda Argote, Interview)

Organizations that follow a codification strategy, i.e. a capturing logic, predominantly use technology to enable the codification, storage and retrieval of individual knowledge (Hansen, Nohria, & Tierney, 1999). In today’s organizations, we find a variety of repository tools such as Wikipedia systems, expert databases and corporate intranets that support this strategy (Yuan, Fulk, & Monge, 2007). Often these tools require a standardized representation of knowledge, which then ensures that it can readily be applied in different contexts (Choi et al., 2010; Nonaka & Takeuchi, 1995). The personalization strategy, on the other hand, promotes a different use of technology. Following a connect logic, knowledge management tools facilitate the identification of knowledge and expertise, rather than the exchange of ready-to-use pieces of knowledge (Hansen et al., 1999). Building on Linda’s statement, we would like to touch upon two technology-related aspects of the connect model. First, we link the model to the research on transactive memory systems and show how recent developments in ICT might allow for an extension of the concept beyond the group-level. Second, we briefly discuss how the very same developments change the nature of work and in doing so indirectly complicate organizational learning.
As Linda explained, the connect model follows the idea of bringing people together, so that they can share their knowledge offline. This necessitates that employees are able to identify those people, who possess the knowledge that they need to perform a given task (K. D. Miller, Choi, & Pentland, 2014). This knowledge of who knows what is embedded in transactive memory systems (TMS), a concept that has been coined by Wegner (1987) and further elaborated by Linda and her colleagues (e.g. Liang et al., 1995). The development of transactive memory systems requires the exposure to other’s expertise (Ren & Argote, 2011). While it is well-established that face-to-face interaction facilitates the development of TMS, research on how ICT influences this process delivers mixed results. Lewis (2004), for example, found no effect of information technology on the development of TMS in teams. On the contrary, Choi et al. (2010) found a positive impact. In part, these developments might be attributed to the technological developments that occurred between 2004 and 2010, as for instance the invention of smartphones or social networking platforms. These tools might have made people more receptive to digital information. Extending this line of argument, Nevo, Benbasat, and Wand (2012) believe that technology will play a central role in extending transactive memory systems beyond the boundaries of small groups. What is more, Ren and Argote state that “transactive memory systems can be artificially created by assigning members to specific domains or by providing members with information about others’ expertise” (2011:202). Indeed, firms have been experimenting for some time with technology-mediated directories and yellow pages in order to increase the visibility and accessibility of hidden knowledge (Armbrecht et al., 2001). However, the success of these tools was often limited. Most of these directories relied on the self-declaration of expertise and people often hesitated to reveal their competence (Armbrecht et al., 2001). Looking at the exponential growth of private and professional networking platforms, such as LinkedIn or Skillpages, it seems that people became less hesitant to provide cues about their expertise. At the same time, more elaborated search mechanisms that tap into various sources of information further simplify the identification of expertise. Extending existing knowledge management system with Web 2.0 tools, such as social networks, blogs and forums, in combination with more elaborate search functionalities, might thus have the potential to affect organizational learning much more positively than previews generations of communication and repository tools (Argote, 2013; Nevo et al., 2012).
“While previous systems operated more as knowledge repositories and directories of declared expertise, new systems provide communication capabilities as well as the capability to identify experts based on who provides answers to queries. The communication capabilities provide rich media for transferring knowledge; expertise identified through the system may be more accurate and useful than self-declared expertise.” (Argote, 2011:444)

Technology fundamentally influences the design and location of work (Fayard & Weeks, 2011). While the advancement in technology enables new ways of connecting people and thereby eases organizational learning efforts, the same development may disconnect people and thus complicate learning. As soon as the ICT infrastructure allowed for more effective and efficient collaboration in distributed teams, organizations started to form their teams according to the skills they need, regardless of the physical location of their employees (Griffith, Sawyer, & Neale, 2003). Encouraged by the same development, alternative work modes, such as home office and mobile working, became more common (Drucker, 2002). The latter development, however, is not only influenced by the advancement of technologies, but more importantly by the people that are using them. The changing locus of work is accelerated by a new generation of employees, the so-called digital natives or the generation Y. This generation of workers is familiar with the use of information and communication technologies tools and use their advantages to rethink when, where and how they work best (Palfrey & Gasser, 2013). Moreover, they are confident enough to question well-established, office-centered patterns of work. As a consequence, direct interactions among team members decrease, while technology-mediated communication becomes increasingly common (Gibson & Gibbs, 2006). Given that face-to-face interaction is best to efficiently share knowledge, it is safe to say that recent developments in technology and the way people use it, will have major implications for management practice and organizational learning research.
Conclusion

In our interview, Linda raised a number of promising avenues for future research. In this essay, we focused on two topics that are related to the recent advancements in technology and their influence on the organizational learning research. First, technology offers novel methods to study learning processes. Second, technology enables new forms of interaction and learning among members within and outside an organization. These two developments suggest new avenues of investigation to advance the organizational learning field.

References


10.4 Paper 4 - Optimal product development through continuous improvement

**Original title:** Optimale Entwicklung mit steter Verbesserung

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OPTIMALE ENTWICKLUNG MIT STETER VERBESSERUNG

Florian Rittiner, ETH Zurich
Nadia Haller, ETH Zurich

Der Respekt gegenüber den Mitarbeitern wird oftmals als das sechste Prinzip der Lean Management Philosophie mitaufgeführt.


Zwischenziele setzen


Verständnis schaffen


symbolisiert jede Karteikarte einen Prozessschritt und enthält die charakteristischen Informationen zur Dauer, der Anzahl beteiligter Mitarbeiter und deren Beschäftigungsgrad (z.B. 3 Personen an 5 Tagen zu je 60%). Anschließend werden Material-, Informations- und Kommunikationsflüsse zwischen den Prozessschritten eingezeichnet.

Tabelle 1: Verschwendung in Entwicklung (Anand & Kodali, 2008)

<table>
<thead>
<tr>
<th>Verschwendung nach dem Lean Management Ansatz</th>
<th>Verschwendung übertragen auf die Produktentwicklung</th>
</tr>
</thead>
<tbody>
<tr>
<td>Überproduktion oder zu frühe Produktion</td>
<td>• Zu viele Produkte oder Projekte</td>
</tr>
<tr>
<td></td>
<td>• Overengineering oder unnötige Funktionen</td>
</tr>
<tr>
<td></td>
<td>• Überspezifizierung oder zu viele Details vorbestimmt</td>
</tr>
<tr>
<td></td>
<td>• Redundante Entwicklung, d.h. keine Wiederverwendung von bereits Bestehendem</td>
</tr>
<tr>
<td>Transport oder Bewegung (in Bezug auf Information und Prototyp)</td>
<td>• Lange hierarchische Struktur für Entscheide und Freigaben</td>
</tr>
<tr>
<td></td>
<td>• Zu viele Schnittstellen oder Quellen für Daten</td>
</tr>
<tr>
<td></td>
<td>• Schlechte Schnittstellenkontrolle oder schlechtes Entwicklungsdatenmanagement</td>
</tr>
<tr>
<td>Unnötige oder zu hohe Bestände</td>
<td>• Schlechtes Konfigurationsmanagement</td>
</tr>
<tr>
<td></td>
<td>• Arbeit an Entwicklungen, die nie benötigt, zu Ende geführt oder verkauft werden</td>
</tr>
<tr>
<td></td>
<td>• Unnötige Dokumente oder physische Prototypen</td>
</tr>
<tr>
<td></td>
<td>• Zu wenig Standardteile eingesetzt, zu wenig Gemeinsamkeiten</td>
</tr>
<tr>
<td>Warten oder Verspätungen</td>
<td>• Unerreichbare Informationen</td>
</tr>
<tr>
<td></td>
<td>• Unklare Entscheidungskriterien oder fehlende Informationen</td>
</tr>
<tr>
<td></td>
<td>• Verspätete Information aufgrund des Freigabeprozesses, Meetings, etc.</td>
</tr>
<tr>
<td></td>
<td>• Warten auf Testresultate oder Prozessinformationen</td>
</tr>
<tr>
<td>Unangebrachter Ablauf oder schlechter Prozess</td>
<td>• Zu viele Meetings ohne Resultate oder fehlendem Konsens</td>
</tr>
<tr>
<td></td>
<td>• Unnötige oder sich wiederholende Aufwände</td>
</tr>
<tr>
<td></td>
<td>• Zu viele Iterationen oder Wiederholungen aufgrund wechselnder Prioritäten oder Anforderungen</td>
</tr>
<tr>
<td>Unnötige Bewegung oder ineffiziente Eigenschaften der Konstruktion</td>
<td>• Zu wenig standardisierte Prozesse</td>
</tr>
<tr>
<td></td>
<td>• Kompliziertes Finden von Informationen</td>
</tr>
<tr>
<td></td>
<td>• Überdefinierte Autorisierung</td>
</tr>
<tr>
<td></td>
<td>• Arbeiten mit falschen oder unvollständigen Informationen</td>
</tr>
<tr>
<td></td>
<td>• Unangebrachte Änderungen (weder durch den Kunde gesteuert noch von Vorteil für die Firma)</td>
</tr>
<tr>
<td>Fehler, Defekte</td>
<td>• Verwendung unreifer oder unangebrachter Technologie</td>
</tr>
<tr>
<td></td>
<td>• Schlechte Konstruktion für Herstellung, Kosten, Zuverlässigkeit, Lieferant</td>
</tr>
<tr>
<td></td>
<td>• Schlechte Lieferantenauswahl</td>
</tr>
<tr>
<td></td>
<td>• Nicht Verstehen und Erfassen der Anforderungen oder schlechtes Verständnis der Kundenbedürfnisse</td>
</tr>
</tbody>
</table>

1. **Plan (Planen):** Das für die Optimierung verantwortliche Team definiert eine erste Massnahme zur Erreichung des Zielzustands, d.h. wie der gewünschte Soll-Prozess erreicht werden soll.

2. **Do (Tun):** Tatsächliche Umsetzung der Massnahme.

3. **Check (Kontrollieren):** Nach der Umsetzung der Massnahme trifft sich das Team zur Diskussion und stellt sich die folgenden Fragen: Was ist gut gelaufen? Was können wir noch besser machen? Warum?

4. **Act (Handeln):** Hat die getroffene Massnahme zur Erreichung des Soll-Prozesses beigetragen, wird der optimierte Prozessschritt standardisiert. Führte die Massnahme (noch) nicht zur gewünschten Prozessverbesserung, wird ein weiterer PDCA-Zyklus angestossen. Das wiederholte Durchlaufen dieser vier Schritte erlaubt die stufenweise Annäherung des aktuellen Entwicklungsprozesses an den gewünschten Soll-Prozess.

**Routine in die Entwicklung bringen**


**Fazit**


**Referenzen**


10.5 Paper 5 – Lean Innovation through Set-Based Concurrent Engineering

**Original title:** Schlanke Innovation durch eine alternativenorientierte Entwicklung

**Co-author(s):** Simge Tuna, stuna@ethz.ch

**Status:** Published in KMU Magazin (Thomas Engeli in collaboration with the EP Verlag)


**Printed version:** Pre-edited manuscript as submitted to the editor
SCHLANKE INNOVATION DURCH
EINE ALTERNATIVENORIENTIERTE ENTWICKLUNG

Simge Tuna, ETH Zurich
Florian Rittiner, ETH Zurich


Effizient und effektiv


Beim konventionellen Entwicklungsansatz, dem sogenannten „Point-Based Concurrent Engineering“-Ansatz, wird eine spezifische Lösung bereits sehr früh und oftmals ohne gründliche Machbarkeitsstudien ausgewählt (Ward et al., 1995). Falls während der Entwicklung technische oder kundenspezifische Schwierigkeiten auftreten, kann dieses frühzeitige Kommittment unnötige Iterationen, teure Nacharbeiten und Verzögerungen im Zeitplan verursachen. Derartige Probleme entstehen oftmals wegen technischer
Überschneidungen verschiedener Funktionen oder veränderter Kundenwünsche, welche erst bei der Prototypenentwicklung oder im ungünstigsten Fall bei der Markteinführung entdeckt werden.

**Frühes Experimentieren**


Abbildung 1: Kontrollierte Konvergenz durch schrittweises Eliminieren unbrauchbarer Alternativen


Tabelle 1: Mögliche SBCE Strategien

<table>
<thead>
<tr>
<th>Wissen</th>
<th>Problematik</th>
<th>Technische Unsicherheit</th>
<th>Strategische Unsicherheit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Experimentieren</strong></td>
<td>Entwickeln von mehreren kleinformatigen Prototypen und Beibehalten hoher Design-Freiheit (Bsp: Toyota)</td>
<td>Reduzieren der Markträtsiken durch Präsenz einer Back-up Lösung nebst einer riskanten Option (Bsp: Automation Inc.)</td>
<td></td>
</tr>
<tr>
<td><strong>Kombinieren</strong></td>
<td>Zusammenfügen der besten Teillösungen zu einem optimalen Design-Konzept (Bsp: Pharma Corp.)</td>
<td>Entwickeln von vielfältigen Modulen für verschiedene Kundennachfrage (Bsp: Denso)</td>
<td></td>
</tr>
</tbody>
</table>
Beispiele aus der Praxis

Bekannte Beispiel aus der Literatur (Toyota und Denso) sowie zwei weitere Cases aus unserer Forschungsarbeit (Automation Inc. und Pharma Corp.) illustrieren im Folgenden wie alternativenorientierte Entwicklungsansätze technische und strategische Unsicherheiten durch Experimentieren und Kombinieren verringern. Und das nicht nur bei internationalen Unternehmen mit grossen Entwicklungsabteilungen, sondern auch bei KMUs, wie unsere Beispiele zeigen.


**Denso:** Denso, ein führender Automobilzulieferer für Heizsystem und Generatoren, Tochtergesellschaft von Toyota, entwickelt auf verschiedenen Ebenen mit alternativenorientierten Ansätzen. Denso setzt auf standarisierte Vielfalt und entwickelt beispielsweise Module nicht nur für ein einzelnes Toyota-Modell, sondern betrachtet immer die Anforderungen der gesamte Fahrzeugpalette. Die Produkte sind so aufgebaut, dass die verschiedenen Module miteinander kompatibel sind und sich individuell und gemäss der Anforderungen verschiedener Fahrzeugklassen kombinieren lassen. Zudem werden Komponenten und Baugruppen derart konstruiert, dass sie auf denselben Produktionslinien gefertigt werden können. Damit lassen sich strategische Risiken bei der Investition in Produktionsanlagen minimieren (Sobek et al., 1999; Ward et al., 1995).

Fazit


Referenzen


10.6 Paper 6 – Workspaces for transdisciplinary collaboration

**Original title:** Arbeitsräume für transdisziplinäre Zusammenarbeit: Unternehmens- oder projektspezifisches Planen und Gestalten

**Co-author(s):** Annina Coradi, acoradi@ethz.ch

**Status:** Submitted to KMU Magazin (Thomas Engeli in collaboration with the EP Verlag)

**Reference:** (-)

**Printed version:** Pre-edited version as submitted to the publisher
ARBEITSRÄUME FÜR TRANSDISZIPLINÄRE ZUSAMMENARBEIT: UNTERNEHMEN- ODER PROJEKTSPEZIFISCHES PLANEN UND GESTALTEN

Annina Coradi, ETH Zurich
Florian Rittiner, ETH Zurich


Transdisziplinarität in Innovationsprozessen


Viele, meist grosse Unternehmen, lassen sich von solchen Co-working Spaces inspirieren, bauen Teamräume, Projekthäuser oder ganze Campuslandschaften, um den Austausch zwischen unterschiedlichsten Disziplinen zu fördern. Es verfügt jedoch nicht jedes KMU oder jede Forschungsgruppe an einer Hochschule über die finanziellen Möglichkeiten eines Grosskonzerns oder die Flexibilität eines Startups. Die Herausforderung liegt deshalb bei vielen Unternehmen darin, in den bestehenden Räumlichkeiten mit bescheidenen finanziellen Mitteln multifunktionale Räume für Begegnung und Zusammenarbeit zu schaffen, die zugleich das individuelle und interaktive Arbeiten der einzelnen Mitarbeiter unterstützen.

**Neue Arbeitsräume für neue Arbeitsformen**

Inter- und transdisziplinäre Aufgabenstellungen und die Einführung neuer Informations- und Kommunikationstechnologien resultieren in neuen Arbeitsformen, welche sich in ihren Anforderungen teils ergänzen, teils widersprechen. Zum einen wächst das Bedürfnis nach persönlichen und ungeplanten Interaktionen über Fachgrenzen hinweg, und zum anderen

Wissenschaftliche Studien zeigen, dass die Arbeitsumgebung einen direkten Einfluss auf die Bewegung, Begegnung und Kommunikation der Mitarbeiter und damit sowohl auf deren Kreativität als auch Effizienz hat. Der Einfluss des Raumes auf den Denk- und Arbeitsprozess konstituiert sich aus drei Faktoren: die Funktionalität des Designs, die Bedeutung der Räumlichkeiten und der Objekte im Raum und die Ästhetik⁷. Je nach Ausgestaltung dieser drei Faktoren werden die Mitarbeiter bei der Ausübung ihrer Aufgaben unterstützt oder gehemmt, wobei die Funktionalität einen deutlich höheren Stellenwert als die Ästhetik einnimmt. Funktionalität wirkt sich langfristig auf die Bewegung, Begegnung und Kommunikation der Mitarbeiter aus, während die Ästhetik tendenziell nur kurzfristig positive Effekte erzielt. Aufgrund dessen ist es wichtig im

Vorfeld von Umgestaltungen oder Neubauten die funktionalen Arbeitsmuster der Mitarbeiter zu analysieren. Nur eine sauber durchgeführte Bedürfnisanalyse lässt Rückschlüsse auf die notwendigen Interaktionen und individuellen Tätigkeiten im Unternehmen zu. Hierbei wird die Dauer, die Häufigkeit, der Ort, die Akteure, die Form und die Abfolge der verschiedenen Kommunikations- und Kollaborationsprozesse erfasst. Bei diesen umfangreichen Analysen können verschiedene Methoden angewandt werden. Deren Zusammenstellung und Ausprägung hängt dabei direkt von den Voraussetzungen und Bedürfnissen des Unternehmens ab. Im Folgenden stellen wir einige dieser Methoden vor und zeigen, wie wir diese für die Bedürfnisanalyse zur Umgestaltung des Transdisziplinären Lehr- und Forschungslabors der Umweltwissenschaften (USYS TdLab) an der ETH Zürich eingesetzt haben.

**Fallstudie im TdLab der ETH Zürich**

Das TdLab fokussiert sich auf die Bearbeitung komplexer Probleme an der Schnittstelle zwischen Wissenschaft und Gesellschaft im Umweltbereich. Die komplexen Aufgabenstellungen und die hohe Variabilität der Projektteams hat das TdLab dazu bewogen, die Arbeitsräumlichkeiten neu zu planen und umzugestalten. Die Arbeitslandschaft sollte zugleich Raum für Forschung, Lehre und Kollaborationen in der Wirtschaft bieten. Das TdLab liegt auf einem Stockwerk und verfügt über eine Gesamtfläche von 160m². Das Lab besteht aus drei fixen und vier flexiblen Arbeitsplätzen in vier Büroräumen (4, 5, 9, 10.1), einem Meeting Raum (1.1) und zwei Seminar Räumen (6, 7) (Bild 1). Die Auslastung der Räumlichkeiten und Anzahl Nutzer fluktuieren stark, wobei lediglich zehn Personen fix dem TdLab zugeteilt sind. Die Räumlichkeiten erfüllen Anforderungen für die Forschung (Einzelarbeit und Arbeit in kleinen Teams) und grösstenteils für die Lehre, aber sie bieten kaum Raum für transdisziplinäre Begegnungen und Zusammenarbeit.
Planungsphase: Methoden der Bedürfnisanalyse

Tabelle 1: Analysetools zur Erhebung von Bewegung, Begegnung und Kommunikation in Relation zu Arbeitsräumlichkeiten

<table>
<thead>
<tr>
<th>Methode</th>
<th>Nutzen</th>
<th>Vor- und Nachteile</th>
</tr>
</thead>
</table>
| Management Interview*                        | • Bedürfnisse des Managements  
• Bedürfnisse der Mitarbeiter  
• Unternehmensziele  
• Unternehmensstrategie  
• Projektrahmen | + Expertenwissen  
+ aktuell  
+ geringer Kostenaufwand  
+ ideal für alle Unternehmensgrössen  
+ Fokus auf fundiertem Verständnis der Prozesse  
- subjektive Empfindungen können zu Verzerrungen führen  
- hoher Zeitaufwand |
| Mitarbeiter Interview*                       |                                                                        |                                                                                                                                                  |
| Nichtteilnehmende Beobachtung*               | • Kommunikationsmuster  
• Formen der Zusammenarbeit  
• Bewegungsmuster  
• Nutzung der Räumlichkeiten  
• Auslastung der Räumlichkeiten  
• Prozessabläufe  
• Arbeitskultur | + tatsächliches Verhalten  
+ quantitative und qualitative Erhebungen möglich  
+ Fokus auf fundiertem Verständnis der Prozesse  
+ ideal für kleine Unternehmen  
- hoher Zeitaufwand  
- hoher Kosten- und Personalaufwand |
| Online Survey*                               | • Kommunikationsflüsse  
• Auslastung der Räumlichkeiten | + geringer Kosten- und Zeitaufwand  
+ Fokus auf mittlere und grosse Unternehmen  
+ Fokus auf quantitativen Angaben  
- kein fundiertes Verständnis der Prozesse |
| Workshop*                                    | • Nutzertypen  
• Prozessabläufe  
• Kommunikationsmuster  
• Formen der Zusammenarbeit  
• Arbeitskultur | + partizipativ  
+ aktuell  
+ geringer Kosten- und Zeitaufwand  
+ ideal für alle Unternehmensgrössen  
+ Fokus auf fundiertem Verständnis der Prozesse  
- keine quantitativen Angaben  
- Gruppendynamik kann zu Verzerrungen führen |
| Soziale Netzwerkanalyse                      | • Kommunikationsmuster  
• Formen der Zusammenarbeit  
• Prozessabläufe | + geringer Kosten- und Zeitaufwand  
+ ideal für mittlere und grosse Unternehmen  
+ Fokus auf quantitativen Angaben  
- kein fundiertes Verständnis der Prozesse |
| Soziometrische Geräte                        | • face-to-face Kommunikation  
• Interaktionen  
• Bewegungsmuster  
• Prozessabläufe | + ideal für mittlere und grosse Unternehmen  
+ Fokus auf quantitativen Angaben  
- kein fundiertes Verständnis der Prozesse  
- abhängig von der Technologie  
- Vertraulichkeit der Daten muss gewährleistet werden |

* angewandt im TdLab

**Ergebnisse der Bedürfnisanalyse: Ein neues Raumkonzept für das TdLab**

Die Bedürfnisanalyse hat interessante Ergebnisse hervorgebracht, die wir im Rahmen dieses Artikels leider nur ansatzweise diskutieren können. Aktuell wird im TdLab durchschnittlich 70% individuell und in leiser Umgebung gearbeitet (Bild 2). Mehrheitlich handelt es sich um kreative Aufgaben. Ungeplante Interaktionen oder Kollaborationen on the spot kommen nur selten vor. Meetings und Pausen werden im Meeting Raum (10.1) abgehalten. Die Seminar Räume (6,7) werden durchschnittlich einmal wöchentlich für Gruppenaktivitäten genutzt und dienen ansonsten als flexible Arbeitsplätze. Um Kreativität und Innovationskraft im TdLab zu steigern, sollte in Zukunft die Präsenz der Mitarbeiter, die face-to-face Kommunikation und die ungeplanten Begegnungen deutlich erhöht werden. Im Gegenzug dazu sollte sich der Koordinationsaufwand zwischen den Akteuren stark reduzieren, um die Effizienz zu erhöhen. Das Bedürfnis nach gemeinsam nutzbaren, funktionsspezifischen Räumlichkeiten ist gross.
Basierend auf der Bedürfnisanalyse haben wir sechs Stellschrauben, respektive Gestaltungsprinzipien für die zukünftige Arbeitswelt im TdLab abgeleitet. Die Stellschrauben adressieren die drei Dimensionen im Raum:

1. Die Kreation und das Teilen von Ideen fördern  
   (Funktionalität)
2. Die unterschiedlichen Arbeitsstile unterstützen  
   (Funktionalität)
3. Die Visibilität der Arbeitsprozesse und von Mitarbeitern erhöhen  
   (Funktionalität/Ästhetik)
4. Die Koordinationsaufwände zwischen Projektpartnern reduzieren  
   (Funktionalität)
5. Die Identität des TdLab’s im Raum spürbar machen  
   (Bedeutung)
6. Den sozialen Austausch fördern  
   (Bedeutung)
Bild 3: Trennung zwischen stillen und lauten Zonen im Szenario Inter-Aktion

Bild 4: Projekträume statt Mitarbeiterbüros im Szenario The LAB

Bild 5: Zur Ausgangslage im TdLab gehören undefinierte Flächen, unbestimmte Kommunikationszonen, standardisierte Einrichtung
**Fazit: Räumlichkeiten zusammen mit den Mitarbeitenden weiterentwickeln**


*Bild 6: Planungs- und Gestaltungsprozess transdisziplinärer Arbeitsräumlichkeiten*