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Innovation in small and medium-sized companies: Knowledge integration mechanisms and the role of top managers' networks**

Past research has revealed that knowledge integration is an important prerequisite for the success of new product development. For this reason, companies deploy a number of formal mechanisms to foster integration across multiple functions and hierarchical levels. In many SMEs, however, such formal mechanisms are complemented or even replaced by informal social networks among managers and employees. Despite the relevance of intraorganizational networks, past research on SMEs, however, was focused mainly on the interorganizational level of analysis. To cover this gap, we map ego networks of senior managers in SMEs and explore their knowledge exchange relationships both inside and across functional and hierarchical boundaries. Our study shows that these social networks are an essential driver of knowledge integration and innovation.

Key words: **SMEs, social networks, innovation, cross-functional integration, top managers, knowledge creation**
(JEL: L64, M12, O31, O32)

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Introduction

Previous research has delivered strong theoretical and empirical evidence that successful product innovations result from the ability of organizations to share and create new and relevant knowledge (e.g. Nonaka & Takeuchi, 1995). In particular, it is argued that the organizational "combinative ability" (Kogut & Zander, 1992), that is flexible integration of the specialized knowledge of various organizational members (Grant, 1996), plays a critical role for innovations. Contrary to the past, as "expertise could be centralized in a single person who knew […] the product technology, production process, and means to market goods to others" (Griffin & Hauser, 1996, p. 192), now an intensive cooperation and knowledge flow between different functional specialties (e.g. Maltz et al., 2001, p. 72) as well as hierarchical levels (e.g. Aalbers et al., 2011) becomes an important precondition for product innovation. Past research has revealed that particularly for highly innovative products, knowledge integration within organizations plays a crucial role in increasing new product performance (Tsai et al., 2012). Previous studies also identified a number of integration mechanisms by which cross-border exchange of knowledge within organizations can be fostered (e.g. Griffin & Hauser, 1996; Leenders & Wierenga, 2002). For instance, in a comprehensive review of empirical work into the success factors of new product development (NPD), Ernst (2002) found that cross-functional project teams have both a direct and an indirect positive effect on the success of new products (Ernst, 2002). More specifically, as argued by Griffin and Hauser (1996, p. 204), such cross-functional product development teams "lead to higher marketplace success and shorter times to market by decreasing the barriers of functionally specialized thought worlds, languages and organizational responsibilities and providing a forum in which information is utilized better, decisions are made more effectively, and conflicts are resolved." In a similar vein, Valle and Avella (2003) found that firms which use cross-functional teams, are characterized by a more effective NPD process (that is, lower development times and costs, and superior products) and a higher percentage of new products that are successful in the market.

In addition to cross-functional teams, a large number of empirical studies identified the support of senior management as a critical success factor of NPD (e.g. Brown & Eisenhardt, 1995; Cooper et al., 2004a). Senior managers provide the NPD team with the financial and political resources necessary to accelerate the progress of development projects (Brown & Eisenhardt, 1995). Moreover, senior managers help the NPD team to align their projects with the firm's overall strategic orientation. Thus, as Aalbers et al. (2011, p. 5) point out, "vertical cross-hierarchy ties can provide the team with access to knowledge and information of a different nature than that which the team accesses through its horizontal cross-unit ties." Accordingly, the participation of senior management in the gate meetings is seen as an important mechanism for knowledge integration within the new product development process (e.g. Cooper et al., 2004a).

While numerous studies have addressed multiple aspects of integration and its impact on innovation performance, one important issue is still under-explored. In the samples of previous empirical studies big organizations were largely overrepresented

(e.g. Griffin, 1997; Hauschildt & Salomo, 2011) and the contingencies of small and medium-sized enterprises (SMEs) have not been considered in a comprehensive manner. This is a critical point, since, as Welsh and White (1981) note, "a small business is not a little big business". Thus, management principles that have proven to be successful in large companies may prove the opposite in SMEs (Welsh & White, 1981). As SMEs constitute over 99 percent of all companies in the European Union, reinforcing national economies by their employment offers and revenues (Eurostat, 2009), a focused analysis of knowledge integration in these companies is important from both the theoretical and the practical perspective.

With respect to the SMEs-related contingent factors, three important issues call for a deeper investigation. First, past studies paid a particular attention to the integration between research and development and marketing (e.g. Maltz et al., 2001; De Luca & Atuahene-Gima, 2007). However, at least in the industrial context, the innovation process not only implies the development of ideas for new market-oriented products, but also the fabrication, assembly, installation of these products etc. Hence, other functions and their specific contribution to innovation have also to be considered.

Second, past studies defined knowledge integration mechanisms as formal processes and structures that ensure the capture, interpretation, and recombination of technology, market and other types of knowledge among different functional units within the firm (De Luca & Atuahene-Gima, 2007, p. 95, 97; Tsai et al., 2012, p. 26). In doing so, previous studies have focused primarily on the horizontal mode of integration. Research dealing with the vertical integration of knowledge across hierarchical barriers, in contrast, is scarce (e.g. Aalbers et al., 2011; Fliaster, 2004). Past studies indicated, however, that particularly in SMEs, CEOs themselves are often highly involved in NPD projects (e.g. Blessin, 2001). For this reason, a deeper examination of vertical knowledge integration activities carried out by senior decision-makers in SMEs is expected to deliver new and valuable insights.

Third, previous research on knowledge integration has focused primarily on formal mechanisms, such as the use of regular reports and memos, formal information-sharing meetings, project reviews etc. (De Luca & Atuahene-Gima, 2007; Tsai et al., 2012). On the contrary, in many SMEs, interaction and collaboration among managers and employees usually occur on an informal basis (e.g. Rüggeberg & Burmeister, 2008; Verworn et al., 2000). Hence, it can be expected that in SMEs formal knowledge integration instruments are also likely to be complemented or even replaced by informal mechanisms, particularly the social networks among the organizational members. Current research on intraorganizational networks revealed that these networks build a valuable source of competitive advantages, facilitating cross-border resource exchange, cross-functional team effectiveness, and the creation of intellectual capital, just to mention a few (e.g. Adler & Kwon, 2002; Nahapiet & Ghoshal, 1998). Consequently, the social networks that particularly contribute to the success of NPD in SMEs have to be analyzed in more detail.

In view of these three gaps, to gain a better understanding of product innovation in SMEs, we explore the role that the intraorganizational social networks of senior managers play in both the horizontal (cross-functional) and the vertical (cross-

hierarchical) modes of knowledge integration. In doing so, we first elaborate these three issues from a theoretical perspective and then address them empirically. Accordingly, this paper is organized as follows. First, we review the literature related to cross-functional and cross-hierarchical knowledge integration in the course of new product development and present typical formal organizational mechanisms that foster both modes of integration. In a second step, we introduce the social network perspective and highlight the relevance of informal networks for knowledge integration. Third, we describe the methodology and discuss the results of an explorative multi-case study of knowledge integration in successful German SMEs in the mechanical engineering industry. Finally, the limitations of our study and its implications for further research as well as from managerial perspective are presented.

Theoretical Background

Knowledge integration between functions: R&D, marketing, production

As mentioned above, the idea that an effective and efficient knowledge integration between R&D and marketing is a critical success factor for product innovation is currently "widely recognized" (Leenders & Wierenga, 2002, p. 305). For instance, many examples suggesting that communication among marketing and R&D enhances new product success have been summarized by Griffin & Hauser (1996). More recently, the data from 148 pharmaceutical companies collected by Leenders and Wierenga (2002) also showed that a significant proportion of variance in new product performance can be explained by the use of mechanisms that integrate marketing and R&D in the new product development process, such as using an influential cross-functional phase review board.

Compared to the R&D-marketing interface, however, much less attention has been paid to the links between marketing and manufacturing (Song & Swink, 2002) as well as between R&D and manufacturing (Brettel et al., 2011). From the theoretical perspective, however, both links are likely to be instrumental for successful innovations. Particularly radically new products developed by R&D often call for significant changes in the manufacturing technology and production routines (e.g. Utterback & Abernathy, 1975), and thus R&D and production ideally have to agree on technical requirements prior to producing the new product on a large scale (Brettel et al., 2011). Vice versa, new production techniques as well as new materials and components enable companies to develop and design products with new technical features and functions. As a result, there is a need for both R&D and production and operations unit to share knowledge and to collaborate. The same is true with regard to the cross-functional integration (CFI) between marketing and manufacturing since these functions also have complementary expertise by which both can contribute to the success of NPD projects. For instance, "where manufacturing is aware of market demand with regard to volumes and variety characteristics, they are more likely to adequately address capacity and flexibility requirements of the product process design" (Brettel et al., 2011, p. 255). In line with these theoretical arguments, empirical research reveals that the integration of production and R&D has a strong positive impact on efficiency in the product development phase while integration between production and marketing shows a positive impact on effectiveness in the commercialization phase (Brettel et

al., 2011). By and large, one can currently conclude that "any thorough exploration of the relationship between cross-functional cooperation and NPD success must consider manufacturing's perspective" (Song et al., 1997, p. 35).

However, when focusing on the interfaces between these key functions, previous studies have not addressed the role played in the innovation process by another important actor – the *installation management unit*. We argue that particularly in manufacturing companies that pursue the competitive strategy of differentiation-based focus (Porter, 1985), developing technologically sophisticated customized solutions, this role is quite essential. Current studies of successful German SMEs – so-called "hidden champions"– indicate, for instance, that workers who are responsible for installation and commissioning of machinery, even of complete production lines at the customer site, can be an essential source for innovations (Simon, 2012, p. 286). Thus, we argue that especially in SMEs within industries such as machine building, the installation management unit has also to be integrated with other functional specialties, such as R&D (e.g. design engineering and development), marketing and manufacturing. In the empirical part, we pay particular attention to this organizational unit and its cross-functional and cross-hierarchical integration.

Knowledge integration across hierarchical levels

An effective integration between functional units is a necessary but not sufficient condition for successful innovations. As mentioned by O'Sullivan (2000, p. 408), "a central finding of the literature on innovation is that the learning that generates higher quality and/or lower cost products occurs through a process that is organisational." From organization theory's perspective (e.g. Picot et al., 1997), any organizational structure has to meet two fundamental requirements: It has to satisfy the need for specialization and professionalization (division of labor) *and* the need for communication and coordination between specialized individuals and units (integration). Accordingly, the specific "way how work is organized – how it is divided and integrated – shapes the extent to which, and the manner in which, knowledge is generated" (O'Sullivan 2000, p. 408) as well the manner in which knowledge is shared and integrated.

As a result of "how work is organized" companies not only consist of different functions but also of different levels in the organizational hierarchy. Consequently, in addition to the "functional segmentation" of different groups of technical specialists, Lazonick (1997) identified two other dimensions of "organizational segmentation" that affect organizational learning and innovation and are related to organizational hierarchy – the segmentation between managers and workers and the segmentation of those top managers who control enterprise resources from those lower in the managerial hierarchy. In particular, as people move up the organizational ladder, they accumulate specialized knowledge about different phenomena and develop a characteristic way of thinking, that is, a characteristic way of evaluating, selecting and processing knowledge (Schein, 1996). Hence, the necessity not only for cross-functional but also for cross-hierarchical knowledge integration (CHI) emerges. First and foremost, organizations need "leaders who are not afraid to face reality as it is rather than pretending it is as they would like it to be" (Kets de Vries, 2002, p. 5). To face that reality, senior managers must encourage knowledge sharing in the bottom-up direction, giving

to workers at the shop floor (such as installers and design engineers) an opportunity to provide a direct and honest feedback and transmit their creative ideas to the top level. Moreover, thanks to a successful CHI, "supportive supervisors" not only keep informed about how employees think and feel but also explain their actions to employees in the top-down mode providing guidance and orientation and contributing to their motivation (Cummings & Oldham, 1997). Thus, in addition to CFI, the integration across different levels of organizational hierarchy (CHI) can substantially contribute to organizational innovation activities.

Formal and informal mechanisms of knowledge integration

On the whole, past NPD research has identified a broad spectrum of integration mechanisms. For instance, Griffin and Hauser (1996) explored six general approaches that companies have been using to integrate the efforts of marketing and R&D: relocation and physical facilities design, personnel movement, informal social systems, organizational structure, incentives and rewards, and formal integrative management processes (i.e. a phase-review process, the Stage-Gate process and the quality function deployment). In particular, Griffin and Hauser (1996, p. 204) argued that both the formal review process and the Stage-Gate process increase product success and decrease development time since they encourage task completion and decision-making and allow the technical and market uncertainties of projects to be reduced. With regard to the Stage-Gate process, the work by Cooper, Edgett and Kleinschmidt (2002, 2004b) as well as other scholars (see Ernst, 2002 for a literature review) indicate that this formalized comprehensive approach that systematically guides innovation projects from idea to launch is a key to NPD success.

Drawing on the study by Griffin and Hauser (1996), Leenders and Wierenga (2002) extended the list of integration mechanisms by information and communication technology (ICT) and examined the effectiveness of these mechanisms with data collected from large pharmaceutical companies. In particular, Leenders and Wierenga (2002) found that while for 45 per cent of the companies formal integrative management processes are very important or the main decision-making body, only about 30 per cent of all managers have experience with "informal survival trips" (which they used in the study as a proxy for informal integration mechanisms) (Leenders & Wierenga, 2002, p. 305).

By and large, the formal management processes specify "what tasks are completed in what order by whom" (Griffin & Hauser, 1996, p. 209). Based on this interpretation, formality in the context of new product development can be described as a set of dedicated explicit rules that govern various intraorganizational activities associated with product innovation (in particular, sharing and creation of knowledge as well as coordination). In these terms, formality refers to both processes (such as the Stage-Gate process) and structures (such as cross-functional teams or review boards) (e.g. De Luca & Atuahene-Gima, 2007) since both of these mechanisms formally define and prescribe patterns and procedures of interpersonal interactions. The formal organization is characterized by prescribed and stable structures as well as defined communication flows that strictly follow the formal channels, and it includes organizational members indicated by formal position, functional duties and authority (Gray &

Starke, 1984, p. 412). On the contrary, in the informal organization the structure is emergent and dynamic, the information flow cuts across formal channels, and only those individuals who deemed 'acceptable' are included (Gray & Starke, 1984).

As mentioned above, previous NPD-related studies focused particularly on the formal integration mechanisms, such as standardized reports and memos and formal analysis of successful and failing product development projects (De Luca & Atuahene-Gima, 2007; Tsai et al., 2012). However, the importance of informality, spontaneity and rule-breaking has been strongly emphasized in the innovation literature (see for an overview Conway & Steward, 2009). Furthermore, creativity studies also demonstrate that an excess of formal structures and processes has a detrimental effect on creativity (Amabile, 1997). It is worth to note that particularly SMEs show "a notable tendency for informality in managerial action, resulting from spatial and social proximity between owners, managers and labor" (Marlow et al., 2010, p. 954). Marlow et al. (2010, p. 955) argue that this proximity "can be drawn upon to engender employee commitment, enable swift decision making, facilitate mutual problem solving and so add to competitive advantage." As mentioned by Marlow et al., (2010, p. 957), informality thereby "is embedded in a commonsense way as practices that evade or challenge formality, face-to-face rather than procedural or bureaucratic".

In sum, the informal organization can become "a valuable mechanism through which 'fresh' ideas and information filter into the innovation process, and as such, it represents an important 'intangible' organizational resource that is difficult for competitors to replicate" (Conway & Steward, 2009, p. 329). More specifically, as argued by Griffin & Hauser (1996, p. 205) "developing informal cross-functional networks reduces the language, thought world, and physical barriers to integration, enables more information to be communicated and utilized, increases coordination and decision-making, and decreases project uncertainties, leading to higher success […]." Especially in organizations with flat hierarchies, such as SMEs, "more and more of what was once thought of as determined by bureaucratic rules emerges from network relations" (Raider & Burt, 1996, p. 198).

Thus, due to the lack of research on informal integration mechanisms, the investigation of the informal knowledge exchange and integration networks across functional and hierarchical boundaries in SMEs can deliver valuable insights. In the following section, we briefly describe key aspects of social network analysis that build the conceptual framework used in our empirical study.

Informal social networks as a means for knowledge integration

In contrast to the formal organization, which can be easily captured by explicit workflow descriptions and organizational charts, gaining insight into the informal organization is a difficult task (Awazu, 2004). In recent years, the volume of social network research in management and organization studies addressing this challenge has increased drastically (Borgatti & Foster, 2003; Kilduff & Brass, 2010). Generally, a network is defined as a set of nodes (actors) connected by a set of ties of a specified type, such as friendship or task advice (Borgatti & Foster, 2003, p. 992; Borgatti & Halgin, 2011, p. 1169). As the aim of our study is to explore knowledge integration in SMEs and the specific role the social networks of senior managers play in this regard, we focus on

knowledge networks. Following Phelps et al. (2012, p. 1117, 1156), we define a knowledge network as a set of nodes (i.e. managers and employees) that serve as repositories of distinctive knowledge and are interconnected by social relationships that enable and constrain their efforts to acquire, transfer and create (e.g. recombine) new knowledge.

In general, social network research has extensively covered multiple levels of analysis – the interorganizational networks in which actors are organizations or their representatives as well as interpersonal networks in which actors are people in organizations (e.g. Carpenter et al., 2012; Phelps et al., 2012). The bulk of SME-related studies, however, have focused on interorganizational networks (e.g. Gronum et al., 2012; Jenssen & Nybakk, 2013), while the interpersonal knowledge networks within SMEs are still underexplored. To address this gap, our study particularly refers to how social relationships of senior managers in SME's influence their knowledge-related activities, especially the integration of knowledge across functional and hierarchical barriers.

In the burgeoning social network literature especially three dimensions of social networks are thematized: the structure of the network, the characteristics of dyadic ties and the features of the actors (e.g. the resources they possess) (Nahapiet & Ghoshal, 1998; Gabbay & Leenders, 2001; Kilduff & Brass, 2010). With regard to the structural dimension, the "structural holes theory" (Burt, 1992) plays a crucial role as one of the most influential „homegrown theories, developed within the social network research tradition" (Kilduff & Brass, 2010, p. 343). According to Burt (1997, p. 340), the "structural hole is an opportunity to broker the flow of information between people and control the form of projects that bring together people from opposite sides of the hole." As our study deals with integration of knowledge possessed by specialized actors in various functional units and at various hierarchical levels in the organization, Burt's argument that "idea generation at some point involves someone moving knowledge from this group to that, or combining bits of knowledge across groups" (Burt, 2004, p. 356) is of particular relevance (see for a detailed discussion Burt, 2000; Burt et al., 2013; Borgatti & Halgin, 2011).

In addition to the network structure, another important characteristic of social networks is the relational dimension that refers to the quality of the actor's dyadic ties (Nahapiet & Ghoshal, 1998; Phelps et al., 2012). In this regard, particularly the concept of tie strength (Granovetter, 1973) has been widely discussed in the network literature (e.g. Perry-Smith, 2006; Borgatti & Halgin, 2011; Phelps et al., 2012). The strength of an interpersonal tie usually reflects the duration of the relationship, its emotional closeness and the frequency of communication (Granovetter, 1973; Marsden & Campbell, 1984; Reagans & McEvily, 2003). Strong ties have been found to foster the development of trust and the norm of reciprocity which, in turn, are important preconditions for the willingness of actors to circulate their knowledge (e.g. Levin & Cross, 2004; Uzzi & Lancaster, 2003). Moreover, past research has shown that strong ties facilitate the exchange of tacit knowledge (e.g. Hansen, 1999). Weak ties, on the contrary, are likely to connect partners from different, non-overlapping social clusters, providing access to diverse knowledge (Granovetter, 1973; 1983), which in turn fosters creativity and knowledge creation (Phelps et al., 2012; Perry-Smith, 2006). Moreover, weak ties are expected to require lower costs in terms of time

and energy needed for establishing and maintenance (Fliaster & Spiess, 2008). On the other hand, since weak ties are associated with lower help motivation, they are also less available and reliable than strong ties (Granovetter, 1983; Reagans & McEvily, 2003).

In addition to these two "generic" forms of network ties, mixed, or hybrid forms have been also identified in the literature. In particular, Levin & Cross (2004) found that employees receive their most useful knowledge at work from "trusted weak ties", that is, ties which are below average in tie strength (e.g. closeness of a working relationship and communication frequency) but above average in perceived trustworthiness.

Finally, the resources residing in the network make up the third important network dimension (e. g. Gabbay & Leenders, 2001). As stressed by Borgatti and Foster (2003, p. 1004), "an actor's success is a function of the quality and quantity of resources controlled by the actor's alters". With regard to knowledge networks, this dimension remains under-investigated, except for the distinction between tacit and explicit knowledge (e.g., Hansen, 1999). Yet, the empirical studies conducted by Cross and his colleagues (Cross et al., 2001; Cross & Sproull, 2004) deliver valuable insights into this topic. These studies reveal that via network relationships business consultants and managers mobilize five different components of actionable knowledge: solutions (both know-what and know-how), referrals (pointers to other people or databases), problem reformulation, validation, and legitimation. Because of the generic nature of these components we argue that they are also likely to be of relevance for other categories of knowledge workers, especially people who are involved in product innovation activities. Table 1 provides a brief description of these knowledge components.

Table 1: Components of actionable knowledge managers mobilize through social networks according to Cross et al. (2001) and Cross & Sproull (2004)

Knowledge component	Description
Problem solutions	Consist both of declarative knowledge (know-what) and procedural knowledge (know-how).
Referrals	This meta-knowledge does not represent a final solution to the problem at hand. Instead, knowledge sources provide pointers to other people with requisite expertise or pointers to specific information in a database.
Problem reformulation	Knowledge provider helps the advice seeker reformulate the problem at hand either through the consideration of additional dimensions and aspects and/or through the anticipation of consequences of planned actions and concerns that are likely to appear in the future.
Validation	The ideas of the advice seeker are validated by the knowledge provider.
Legitimation	Advice seeker discusses her ideas with an influential person to increase the credibility of these ideas for outsiders and obtain approval for a course of action.

Based on these key network characteristics, in the empirical part we explore the informal knowledge networks within SMEs and how they contribute to knowledge integration and product innovation.

Method

Case study methodology and data collection

Due to the lack of research on knowledge networks of senior managers within SMEs, an explorative research design, i.e. the case study methodology was chosen (Eisenhardt, 1989; Yin, 2009). While this methodology makes it possible to get access to a rich variety of both qualitative and quantitative data (Eisenhardt, 1989), it is not intended to make predictions about statistical relationships and frequencies (Eisenhardt & Graebner, 2007; Yin, 2009). Instead, making use of case studies, researchers aim at contributing to theory building. Hence, the conclusions drawn from case study results are "generalizable to theoretical propositions and not to populations or universes" (Yin, 2009, p. 15).

When using the case study method, researchers need to decide whether to apply a single- or a multiple-case design (Yin, 2009). Even though some authors emphasize the persuasive power of single case studies (e.g. Dyer & Wilkins, 1991; Siggelkow, 2007) this design is often associated with several biases (e.g. Tversky & Kahneman, 1986). As a result, "theory building from multiple cases typically yields more robust, generalizable, and testable theory than single case research" (Eisenhardt & Graebner 2007, p. 27). Thus, a multiple-case design was applied in our study.

For reasons of confidentiality, the case organizations will be referred to as Company A, B, C and D in the following section. All companies are SMEs, employing no more than 500 employees (Günterberg, 2012), and they belong to the mechanical engineering industry – either to the packaging or the special engineering industry. In this technology-intensive industry the development of new products plays a crucial role for organizational competitive success (Belitz et al., 2011; Jones, 2007). All four SMEs can be described as "hidden champions" (Simon, 2012): They operate in specialized market niches and even though they are not necessarily well known by general public, they are technology and market leaders in Europe or even in the world.

With regard to data collection, the triangulation of different methods is recommended in the literature to increase internal validity and obtain a comprehensive description of the cases (Eisenhardt, 1989; Yin, 2009). In this study, data was collected especially through semi-structured interviews with key decision makers in NPD at the senior level as well as other employees, since personal interviews are regarded as a powerful tool to gain access to rich empirical data (Eisenhardt & Graebner, 2007). Two to seven respondents were interviewed per company, one interview lasted between one and two hours. Furthermore, several additional information sources were used, such as organizational charts, archival data and detailed manuals for formal innovation management tools, such as Stage-Gate processes. Corporate observations have also been made subsequent to several interviews.

Table 2 gives an overview of the organizations studied including the functional affiliations and the positions of the persons interviewed. The inclusion of employees from different functions and hierarchical positions was critical to gain various perceptions of forms and mechanisms of CFI and CHI in these companies. In doing so, the probability of an informant bias was diminished (Ernst & Teichert, 1998). All inter-

viewees were employed by the companies for several years and have gathered experience in a large number of NPD projects.

To guide the interviews, a semi-structured questionnaire was developed containing several open questions to the levels and mechanisms of CFI and CHI. Before the actual interviews, a pre-test was conducted to avoid the misinterpretation of questions and improve the data quality. The interviews were divided into two parts. The first section aimed at identifying the formal mechanisms of CFI and CHI. The second section was designed to explore the informal integration mechanisms and the role of social networks. For this purpose, qualitative SNA methods were used to uncover the informal knowledge networks of the interviewees. The respondents were given a network map that we designed based on the frameworks suggested by Burt (1984) and Thomas (2009). In particular, this "ego network map" allows to differentiate between contacts within and outside the respective function as well as between contacts with peers and contacts at higher and lower hierarchical levels. Ties that connect ego to persons ("alters") from other functions and other hierarchical levels represent, therefore, bridges across structural holes (Burt, 1992). In explicitly addressing those bridges we also draw on the arguments raised by Tortoriello and Krackhardt (2010) who argue that the traditional identification of bridging advantages with ties spanning holes in an informal social structure ignores the case in which ties span holes defined by a formal organizational structure, "thus leading to underestimation of the impact of social structure on performance in organizations" (Tortoriello & Krackhardt, 2010, p. 179).

Our data collection and network visualization procedure followed to the standard methods of name generators and interpreters as described in the social network literature (e.g. Lin, 2001; Marsden, 2011; Wasserman & Faust, 1994). Accordingly, the interviewees were first asked to name contacts (i.e. peers, supervisors and subordinates) both within and beyond their own function and hierarchical level with whom they most frequently exchange and create knowledge that is relevant for NPD. Thereafter, several name interpreter questions were posed to explore the characteristics of the respondent's contacts ("alters"), the dyadic ties among them as well as the knowledge components that flow through those ties.

Table 2: Overview of cases and interviewees

Case	Product fields	Industry	Number of Employees	Interviewees
Company A	Machinery	Packaging	250	CEO Head of Marketing Head of Design Engineering (2) Head of Product Management Innovation Manager Marketing Manager
Company B	Machinery	Packaging	300	CEO Head of Design Engineering Head of Production Installer Marketing Manager
Company C	Machinery	Special Engineering	75	CEO Design Engineer
Company D	Machinery	Packaging	200	Owner CEO Sales Director

Data analysis

To analyze the data, a computerized content analysis was performed by the use of the software program MAXQDA. Thereby, the inductive approach of category building was applied, as it is typical for exploratory research designs (Mayring, 2002). In line with the suggestions of Eisenhardt (1989) and Miles and Huberman (1984), the data analysis process started with an intensive within-case analysis. Hence, the results of the content analysis were gathered up with further material collected during the sampling period and summarized in a report for each case. Subsequently, a cross-case analysis was conducted. In this step, the results of the case studies were compared and examined in terms of differences and similarities. Through this procedure, it was ensured that the particularities of the individual cases were not neglected, as it may happen in studies using the multiple-case design (Dyer & Wilkins, 1991).

Results of the cross-case analysis

CFI: Key role of the installation management unit

The outcomes of the case studies clearly replicate the findings of previous research illustrating the crucial role of CFI in the development of new products. Nearly all interviewees stressed the importance of knowledge exchange across functional boundaries. Moreover, as we assumed in the theoretical part, not only the integration between marketing, R&D, and production but also the knowledge exchange with the installation management unit plays a central role in the NPD within SMEs. Evidence for this important role has been found in a large number of interviews, for instance:

> "Installers are extensively and strongly involved in the exchange of knowledge and the creation of new ideas." (Head of Design Engineering, Company A)
>
> "The knowledge of installers is decisive for the smooth functioning of the machines at the customer site. Due to the high relevance of the installers' knowledge, coordination between the installation management unit and the development department is quite intensive." (Head of Production, Company B)
>
> "Installers are definitely important partners in the development of new machines. In our company, installers, marketers and design engineers swap their ideas on a daily basis." (CEO, Company C)

The central role of the installation management unit became especially apparent when the ego networks of the interviewees were mapped. Respondents described the ties between all three key functions from the NPD literature – marketing, R&D and production – as strong. The connections with the installers provide both the marketing and the R&D department with important knowledge resources such as solutions, problem reformulations and validation. One installer explained:

> "Our function is important because we are the ones who are in direct touch with the customers when we implement the machines at their site. Since I have started to work for this company, I have listened to numerous problems and requirements of our customers, which makes my knowledge indispensable for the development of new products."(Installer, Company B)

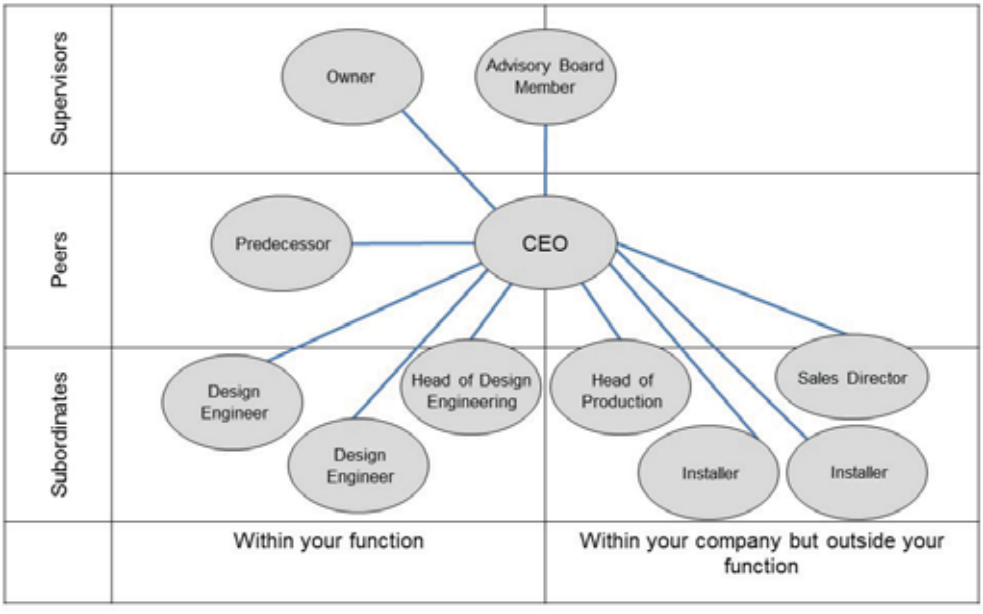
In sum, we could identify three essential contributions installers make to the development of new products. First, they transfer their knowledge regarding customer needs to marketers and design engineers; this happens both formally (by preparing

written installation reports) and informally (by face-to-face communication in informal social networks). This knowledge is extraordinarily useful since it provides guidance for further development, design and optimization of products. Second, very experienced and qualified installers not only transfer their knowledge across functional boundaries, but also engage in the sharing and creation of new knowledge. In this regard, they share their ideas with marketers and design engineers and discuss and brainstorm with them how the problems they were confronted with can be solved in the future. Thus, these activities reflect all key modes of connectivity and knowledge integration suggested by Fliaster (2004) – one-way knowledge transfer (informing), two-ways (dialogical) knowledge sharing and collaborative knowledge creation. Finally, sometimes installers directly act as creative problem solvers and innovators, when the new product (i.e. packaging machine) installed at the customer site is not working as expected and a creative solution needs to be found more or less immediately.

CHI: Key role of the CEOs and their networks

In addition to CFI, high levels of CHI were found in all companies. In this regard, several respondents mentioned the CEOs as important partners in the development of new products. Thus, knowledge integration across hierarchical levels does not occur only between employees and their direct supervisors but also includes the CEOs. The central role of the CEOs in these SMEs becomes particularly evident when their social networks are considered. Figure 1 shows the aggregated knowledge network of the CEOs interviewed in our study.

Figure 1: Aggregated knowledge network of the SME's CEOs



As shown in Figure 1, the CEOs do not only turn to the department heads for the exchange of knowledge. In addition, their knowledge networks also include a number of

highly qualified and experienced employees at the shop floor level. The CEOs explained that they are very selective in terms of tie building: They create and maintain strong ties with a small number of design engineers and installers they perceive as "stars", "top performers" or "professional elite". These employees, who typically work for the company for a large number of years, usually generate the best ideas and show a strong affective commitment (e.g. Meyer & Herscovitch, 2001) to the long-term success of the organization. Through their direct ties to the CEOs, these employees take initiative, raise their voice, transmit dissenting opinions and insist that problems that arise, for instance, between the installation unit and the design engineering unit have to be solved:

> „There are three, four, or five people in those areas. I know all of them by name. They are outstanding people. I would really call them stars." (CEO, Company A)
>
> "They stand in the forefront, they are the elite. The other installers do not turn to me spontaneously." (CEO, Company B)
>
> "I do not turn to anybody and everybody when I want to design a new machine. In fact, there are two people in my engineering design department who are extremely creative and experienced. They are even of high relevance for the long-term survival of the company." (CEO, Company C).

Moreover, the CEOs do not only passively listen to the concerns and ideas of their key installers and design engineers, but also share their own ideas with them. It is worth to note that the CEOs of all SMEs we studied had previously worked in development departments. The knowledge resources provided by these CEOs go beyond validation and legitimation (Cross & Sproull, 2004) or so-called "influential resources" such as strategic direction (Aalbers et al., 2011). In addition, the CEOs strongly contribute to NPD by providing creative problem solutions. Hence, as noticed in previous studies (e.g. Spielkamp & Rammer, 2006), the CEOs in these SMEs combine the roles of the "power promotor" and the "promotor by technological know-how" (Hauschildt & Chakrabarti, 1988; Hauschildt & Kirchmann, 2001):

> "We have a CEO, who himself used to be a design engineer. Therefore, it is in his personal interest to be ahead of the game." (Head of Design Engineering, Company B)
>
> "The main advantage is that the CEO possesses tremendous knowledge and expertise. It's mainly due to his background – he used to be a chief design engineer. He is someone who really knows the stuff. I'd like to call him an all-rounder. He does rely on his talented subordinates but the great ideas come from him." (Marketing Manager, Company A)

Whereas strong direct ties between the CEOs and selected design engineers as well as "star installers" have been uncovered in all companies, some case-specific particularities in the CEOs' networks have also been found. In Company B, for instance, the CEO also maintains direct ties with the members of the advisory board and with his retired predecessor. Both ties can be best described as "trusted weak ties" (Levin & Cross, 2004), as the informal exchange happens only infrequently, but the ties are characterized by a high level of interpersonal trust. In the interview, the CEO emphasized the crucial importance of these relationships for his innovation-related activities and work performance. More specifically, the members of the advisory board are approached by the CEO to informally validate and legitimate new product initiatives in terms of the strategic orientation of the company and thus, to foster the integration of

business and innovation strategy. The tie to the predecessor is very instrumental for the CEO with regard to the receipt of information on various technological, business-related as well as 'political' issues, such as dealing with the company owners and other stakeholders.

In Company D, the network ties between the CEO and the owner also play a crucial role, but in different terms. In this case, the owner, despite his advanced age, still contributes massively to the development of new machines. The CEO as well as the sales director both described him as a "creative genius" with characteristics known from the psychological creativity literature, such as the ability of analogical thinking, high intelligence, questioning of tried and tested problem solutions and a high self-assurance (e.g. Martindale, 2001; Amabile, 1997):

> "He is really creative but also chaotic. He has a lot of great ideas and pushes the company continuously in a new direction." (Sales Director, Company D)

> "Our owner is extremely creative. He generates a lot of new ideas and promotes new technologies." (CEO, Company D)

For the CEO of Company D, the owner is one of his most important network partners in the development of new machines. Important knowledge resources exchanged in this relationship are solutions, problem reformulations and validations both at the technical and the strategic level of NPD. Whereas the owner mainly focuses on technology-related tasks targeting the direction of NPD, the CEO takes the role of a broker (Burt, 1992; 2009), coordinating the activities needed for the practical implementation of the new ideas through his direct network ties to the design engineering, production, and sales departments.

Taken together, the knowledge networks of the CEOs in the SMEs we studied play a central role in the development of new products. The CEOs act as brokers or "network entrepreneurs" (Burt, 1992) transferring, exchanging and creating knowledge through ties that span structural holes between functions and across hierarchical levels. Table 3 summarizes the characteristics of the CEO's knowledge network ties that have been visualized formerly in Figure 1; in doing so it reflects the knowledge resources (tie content), the strength of the ties as well as the innovation outcomes.

With regard to the latter, it is particularly worth to note that, as the interviews show, network ties have a contingent effect on various kinds of innovation. For instance, knowledge ties between the CEO and the installers lead particularly to market pull innovations, which are mostly incremental in nature. On the contrary, in the search for radical, technology-push innovations, the network ties with key installers are less beneficial:

> "The market information provided by the installers is important, for sure. However, this knowledge exchange rather leads to incremental improvements. Real breakthrough innovations do not result from these connections." (CEO, Company D)

In the SMEs we studied, the CEOs mostly received fruitful insights for technology push innovations through their strong ties with key design engineers as well as the heads of design engineering and production departments. In Company D, the owner represents an additional knowledge source for this kind of innovation. Moreover, the ties with senior level employees often result in innovations derived from the business

and innovation strategy. In Company B, these strategy-driven innovations additionally emerge thanks to the trusted weak ties the CEO maintains with his predecessor and the members of the advisory board.

Table 3: Network ties as a means for knowledge integration and innovation: Results of the cross-case analysis

Network ties	Type of knowledge exchanged	Tie strength	Innovation Outcome
CEO – Key installers	All types of knowledge	Strong	Market pull
CEO – Key design engineers	All types of knowledge	Strong	Market pull, technology push
CEO – Department heads (Production, Engineering, Sales)	All types of knowledge	Strong	Market pull, technology push, strategy-driven
CEO – Owner	• Solutions • Problem reformulation • Validation	Strong	Technology push, strategy-driven
CEO – Predecessor	• All types of knowledge	Trusted Weak Ties	Technology-push, strategy-driven
CEO – Members of the Advisory Board	• Validation • Legitimation	Trusted Weak Ties	Strategy-driven

Formal and informal mechanisms of CFI and CHI

Finally, our study explored the concrete mechanisms (e.g. innovation management tools) senior managers deploy to ensure high levels of CFI and CHI in the NPD activities. This aspect is particularly relevant with regard to knowledge networks since it contributes to a better understanding of how social relationships affect the creation and dissemination of new and useful ideas. The mechanisms identified in our study are summarized in Table 4.

Concerning the formal integration mechanisms, several findings of the case studies replicate mechanisms that have been already identified in the empirical literature, such as strategy meetings and regular portfolio reviews (e.g. McDonough & Spital, 2003), the usage of the Stage-Gate process (e.g. Cooper, 1988) and the formation of a cross-functional NPD team (e.g. Brown & Eisenhardt, 1995). Regular formal reports have been also thematized in previous studies as an important integration mechanism (e.g. De Luca & Atuahene-Gima, 2007). In this regard we additionally found that the installation reports that have to be written by the installers right after the new product (e.g. packaging machine) has been installed at the customer site are an essential source of knowledge particularly for the design engineers. Moreover, in Company B and Company D everyday round tables take place, in which the CEO and the heads of production, design engineering and sales units get together to discuss current issues and generate new ideas, also as an immediate response to concrete requests of the customers – a sort of "mail processing meetings".

New insights have been gained particularly with regard to the informal mechanisms of CFI and CHI. With regard to CFI, frequent creative discussions between employees of the three key functions contributing to NPD – R&D, marketing and production – were mentioned by several respondents. Moreover, design engineers frequently accompany installers by customer visits and discuss problems and solutions with them. As suggested by Griffin & Hauser (1996, p. 206) such strong dyadic ties between employees help to manage cross-functional interfaces more smoothly since the dyad participants can become intensely committed to each other resulting in better collaboration.

With regard to CHI it has been already mentioned above that the CEOs maintain strong dyadic ties to several key design engineers and installers at the shop floor level. The most important informal mechanism applied by all CEOs to maintain these relationships and to share and create knowledge is everyday visits into the two departments. For instance:

> „I visit the engineering and design department and the installation management unit once in the evening or early afternoon, when it is a bit quieter down there. I know my 'stars'. Of course, I know at which customer sites they work. I really know who to talk to in order to get the right feedback or new ideas. In these units, in which – I don't know how many, hundred or so people are employed – I find three, four, or five stars that I can talk to." (CEO, Company A)

> "I visit our design engineers and installers on a daily basis. It is very important to be in regular contact with them." (CEO, Company B)

On the other hand, the employees in these departments have the opportunity to go directly to the CEO to discuss urgent matters of NPD. This open-door policy is explicitly pursued by the CEO to overcome barriers to knowledge integration and hence it helps build bridges that span structural holes across various hierarchical levels in the organization.

An interesting observation has been made in Company A that currently demonstrates the highest degree of formalization among all SMEs analyzed in our case study. In this company all formal mechanisms described above are applied. However, many of them have been established only recently, and the person who championed knowledge integration across different functions and hierarchical levels – the CEO – is eligible for retirement and is expected to leave the company in the near future:

> „Through these formalized processes, we try to make sure that people work together and combine their knowledge, so that the bottom line remains the same, even after our CEO has left." (Marketing Manager, Company A)

Thus, the formal integration mechanisms in this company are currently designed in order to mitigate the anticipated negative consequences of the upcoming retirement of the CEO and the loss of his brokerage activities in informal social networks. In other words, prescriptions are expected to substitute history, since the new prescribed formal rules are aimed to replace informal network ties that have emerged in the past during interpersonal collaboration. The result of this ongoing transformation is totally open at the moment.

Table 4: Modes and mechanisms of CFI and CHI: Insights from the case studies

Mode of Integration \ Degree of Formalization	Formal	Informal
Cross-Hierarchical	• Regular portfolio reviews • Mandatory involvement of the CEO in the gate meetings of large-scale projects • Technology meetings • Strategy meetings • Everyday round tables between the CEO and the department heads	• Everyday informal communication between the CEO and the department heads • Everyday visits of the CEO to the production, sales, and installation departments • Open door policy by the CEO and senior managers
Cross-Functional	• Formation of a cross-functional NPD team • Cross-functional NPD process (Stage-Gate) • Formal installation reports • Regular portfolio reviews • Technology meetings • Strategy meetings • Everyday round tables between the CEO and senior managers	• Everyday informal communication between the CEO and senior managers • Intensive creative discussions between employees from different functions (e.g. sales, design, engineering, development and installation) • Designers, engineers and installers collectively install machines at customer sites

Conclusions

Past research has revealed that CFI, primarily between R&D and marketing, essentially contributes to the success of new product development. Above all, formal CFI mechanisms deployed in large-scale organizations, such as cross-functional teams (e.g. Brown & Eisenhardt, 1995) and the Stage-Gate process (Cooper, 1988) have been analyzed in-depth. In this paper, we investigated both the formal and informal mechanisms of knowledge integration between functions as well as across hierarchical levels within SMEs. In sum, our paper makes four contributions to the innovation literature.

First, our study revealed that at least in the packaging and the special engineering industry the installers play a crucial role for the success of NPD. Through strong ties with design engineers and marketers, this function exchanges significant knowledge resources, ranging from final solutions to problem reformulations and thereby is strongly involved in the creation of new knowledge. In sum, we have shown that the integration with the installation unit that has been underexplored in past research substantially contributes to innovations in SMEs.

Second, moving beyond CFI, we argued that CHI is also of crucial relevance for innovation. Both the semi-structured interviews and the network visualization method have shown that the CEOs and other senior managers of the SMEs were permanently engaged in NPD-related CHI activities, maintaining strong ties with the top performing employees at the shop floor level, such as design engineers and installers and ef-

fectively using these ties for sharing and creation of knowledge. In this regard, they take the role of brokers (Burt, 1992), mobilizing and transmitting knowledge for innovation and thus bridging structural holes between functions and across hierarchical levels. This key role the CEOs play may be at least partly traced back to their special interest in NPD, as they had all worked in development departments before.

Third, the number of studies that consider spanning structural holes in the formal organizational structure rather than informal (i.e. social) boundaries is still small (e.g. Tortoriello & Krackhardt, 2010). By explicitly addressing the bridges senior managers build between functions and across hierarchical levels our paper also sheds light on this underexplored and important research issue.

Finally, we explored which formal and informal mechanisms fostering CFI and CHI are established and maintained in SMEs. In particular, the most important informal mechanisms to foster integration across hierarchical levels are everyday visits into the design engineering and installation departments undertaken by the CEOs (the top-down mode) and an open door policy allowing top performers from the shop floor level, such as the best installers, to be proactive and transmit their creative ideas directly to the key organizational decision makers in a bottom-up manner.

Our study is characterized by several limitations that indicate promising directions for future research. First, the number of companies we investigated and the variety of industries in which they operate was limited. Hence, additional contingency factors, such as industry have to be addressed in future research in order to increase the validity of findings. Second, our study was based primarily on qualitative research methods, such as semi-structured interviews and ego network visualization. We argue that future research on intraorganizational knowledge networks within SMEs should also deploy quantitative empirical methods and use not only egocentric but also sociocentric sampling methods and address structural features at the whole network level as well (e.g. Carpenter et al., 2012).

Third, future studies could also focus on the interplay of formal and informal knowledge integration mechanisms. All companies in our case study are innovative and successful but they strongly vary with regard to the degree of NPD formalization. Thus, future studies should address the dynamic relationship between formal and informal integration mechanisms both theoretically and empirically to identify the antecedents as well as the benefits and costs of formalization. In connection to this aspect, from the observation of the brokerage activities in our study another important research question arises. Brass et al. (2004, p. 796) argued that "(…) organizational structure shapes networks in organizations. (…) Because it would be difficult for a superior and subordinate directly linked by a formal hierarchy to avoid interacting, it would not be surprising for an "informal" social network to shadow the formal hierarchy of authority". Our case study shows, however, that the relationship between formal organizational structure and informal interpersonal networks is more manifold and complex than mere shadowing. In addition to the ties to their direct reports that are prescribed by formal hierarchy, or even surpassing these prescribed formal coordination rules, the CEOs build and maintain ties to the employees at the shop floor, and view these ties as exceptionally valuable for innovation. Past theoretical and empirical research is needed to address the relationship between formal structure and

networks and its impact on knowledge sharing and innovation. Our paper provides the first insights for future research on this important issue.

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