The role of users and customers in digital innovation

Abrell, Thomas; Pihlajamaa, Matti; Kanto, Laura; vom Brocke, Jan; Uebernickel, Falk

Published in:
Information & Management

DOI:
10.1016/j.im.2015.12.005

Published: 01/04/2016

Document Version
Peer reviewed version

Abrell, T., Pihlajamaa, M., Kanto, L., Vom Brocke, J., & Uebernickel, F. (2016). The role of users and customers in digital innovation: Insights from B2B manufacturing firms. *Information & Management, 53*(3), 324-335.

https://doi.org/10.1016/j.im.2015.12.005

The Role of Users and Customers in Digital Innovation: Insights from B2B Manufacturing Firms

Abstract

Diffusion of digital technologies into the manufacturing industry has created new opportunities for innovation that firms must address to remain competitive. We investigate the role of customer knowledge and user knowledge in three global B2B manufacturing companies' digital innovation processes. We find that the B2B manufacturing industry's characteristics influence how users and customers may be leveraged. Customers making the purchasing decisions are used for knowledge about short-term changes in market needs, while users working directly with the products provide long-term guidance for digital innovation. We identify practices for acquiring, distributing, and using customer knowledge and user knowledge for digital innovation.

Keywords
digital innovation; customer knowledge; user knowledge; innovation management; knowledge-based view

Introduction

The diffusion of new digital technologies into the manufacturing industry creates new opportunities for digital innovation [1–3]. Combining digital technologies like sensors, RFID tags, and cloud computing with non-digital products and services may give products and services new properties [4] and provide significant opportunities for new innovation [5–8]. Digitization of products is also likely to have significant disruptive effects [8–12] in that firms' competitiveness will depend heavily on the firms' ability to innovate using digital technologies.

Extant research on digital innovation has focused on the use of digital tools to facilitate innovation processes [10,13–15] and the innovation opportunities digital technologies create [4,16–18]. There has also been interest in the managerial challenges associated with digital innovation processes, as the introduction of digital technologies to traditional innovation processes induces changes in architectures, development practices, cognitive framing of problems, organizing logic, and interactions between actors [2,11,17–20]. However, little is known about the factors that influence the success of digital innovation processes [2,4].

To develop digital innovations, firms must have proficiency with digital technologies, but they must also understand about their markets' needs [21], for which they must focus on their customers and users [22–25]. According to the knowledge-based view of the firm, interactions with customers and users can be examined from the viewpoint of customer

knowledge and user knowledge—that is, knowledge *about* customers and users and knowledge obtained *from* customers and users [26]. How firms manage the various types of customer knowledge and user knowledge is an important antecedent of their innovation outcomes [27,28]. User knowledge, in particular, is important for technological innovation and for the development of radical innovations [29].

This study addresses how B2B manufacturing firms leverage customer knowledge and user knowledge for the purposes of digital innovation. We analyze the data from a multi-case study of three firms that are presently adopting digital technologies for use in their product and service designs. The context of the study is that of a heavy manufacturing industry, and the case companies are component, system, and service providers related to, for example, marine vehicles, power plants, and production facilities. In this context, there is a need to distinguish between the roles of customers and users. Users—who are, for example, vehicle or plant operators—are not typically involved in purchasing decisions, and the customers—who make the purchasing decisions—do not directly use the products. The users are located in the customers' organizations or farther down the supply chain. We focus on the differences between customer knowledge and user knowledge with respect to knowledge type and its influence on digital innovation. We also report on the practices firms use in acquiring, distributing, and using customer knowledge and user knowledge to support digital innovation and the challenges they face in doing so.

The study is organized as follows. First, we establish the theoretical background of the study by reviewing the literature on digital innovation and the role of customer knowledge and user knowledge in innovation. Next, we describe our research design, case selection, data collection, data analysis, and research context. Then we report the findings from the three cases. Finally, we explain our contributions to theory and practice.

Theoretical Background

Digital technologies may have two kinds of impact on the innovation processes [1] of the manufacturing industry: They may facilitate the innovation process itself by providing tools with which to improve how innovation process tasks are performed, and they may make new kinds of digital innovations possible by adding new properties to existing non-digital products and services. Following Yoo et al. [17], who build on a Schumpeterian definition of innovation, we define digital innovation as "carrying out new combinations of digital and physical components" to produce novel products and services.

Nambisan [15] reviews the extant literature on the use of digital technologies to facilitate innovation processes. Nambisan identifies four key dimensions of these technologies: First, IT tools for *process management* may help in the adoption of customized process models and promote integration between new product development and other organizational functions. Second, IT-based *project management* systems allow access to project information from diverse sources, which helps in project portfolio management and task coordination. Third, *information management* systems support information capture, sharing, and combination across the organization. Last, digital technologies provide new means of *collaboration and communication*, such as virtual innovation teams. More recent studies have investigated the adoption of digital 3D-visualization tools [10]; the use of digital tools, such as computational chemistry, in drug development [14]; and the effect of simulation models on the automotive development process [13].

The second branch of literature considers the impact of digital technologies on innovation outcomes [1]. As the price-to-performance relationship of digital technologies improves, opportunities for digital innovations open up in diverse contexts [2,3,8]. In the manufacturing industry, digital technologies like sensors, RFID tags, and cloud computing can be embedded into non-digital products and services to produce networked "smart factories" with flexible and adaptive production processes [5,6,7] and give existing non-digital products and services new properties. Yoo [4] proposes seven properties of digital artifacts—programmability, addressability, sensibility, communicability, memorability, traceability, and associability—which provide digital artifacts the ability to modify their operation logics, respond to messages and environmental changes, send and receive messages, record and store information, interrelate events over time, and relate to and identify with other entities. These properties provide significant possibilities for digital innovations [8].

While the innovation potential of digital technologies is widely recognized, few studies address the management of digital innovation processes [17,18,20]. Digital technologies have induced "non-reversible and deep changes in computing infrastructures, development practices, and cognitive framing of computing problems" in both services and development processes [11]. Compared to traditional product innovation, digital innovation poses new challenges with respect to organizing logic, market dynamics, and architectural design [20]. Yoo et al. [17] propose that new digital innovations give birth to novel product architectures that require substantial organizational changes in the innovating companies. Moreover, digital innovation processes may instigate interactions between heterogeneous actors which creates coordination challenges [18]. Additional challenges arise in matching digital and traditional innovation processes with varying paces of development when digital technologies are embedded into non-digital products [2,19].

The diffusion of digital technologies into new areas of application is likely to have far-reaching effects. Digital technologies open new opportunities but in doing so also create competitive pressure. Since digital innovation has the potential to revolutionize the manufacturing industry by disrupting existing product designs and business models [7,30,31], manufacturing firms must learn to adapt to such disruptions in order to ensure their long-term survival [32,33]. In the process of Schumpeterian creative destruction, some firms fail and new entrants take their place, as incumbent firms often have difficulty adapting to disruptions from technological developments [34,35]. When disruptive technologies enter an industry, firms compete to develop novel designs based on new technologies and try out variations based on emerging opportunities [36]. As disruptions create opportunities outside traditional areas, they also enable radical innovation, that is, innovation that creates a new development trajectory [37]. In the end, dominant designs emerge as winners and become industry standards. Under such circumstances, managers should focus on the right innovation processes, but little is known about the factors that influence the success of digital innovation in organizations [4]. Our study addresses this issue.

To develop successful innovations, firms need knowledge about market *needs* and the *solutions* to fulfill those needs [21]. The properties of digital technologies make solutions for a wide range of needs possible [4,8], so understanding what kinds of needs there are and which needs should get the most attention is important. Digital innovation is usually associated with agile innovation processes, characterized by short development cycles and quick accommodation to changing needs [38,39]. However, in the B2B manufacturing industry on which the present study focuses, products are complex and their life cycles are long. Therefore, innovation comes with large investment, and major changes in development trajectories are rarely feasible. Consequently, identifying the right long-term direction early

on is more important in this industry than it is in industries in which frequent adaptive readjustments are more practicable.

Firms must focus on their customers and users to understand the "need side" of innovation. The role of interacting with customers and users in the development of new processes and services has been recognized since the 1960s [22,23,25]. More recently, the literature on open innovation in particular has shown how firms can leverage customers and users to benefit innovation processes. Acquiring users' knowledge by involving advanced users early in the innovation process helps firms to understand their needs and guides development in the right direction [28,40,41]. There is also evidence that orienting innovations on the customer improves the innovations' performance in times of technological turbulence [42,43]. Because of the wide use of IT technologies, new ways to acquire customer knowledge and user knowledge, such as online forums on product web sites and open source communities, have emerged [44,45]. Companies are also turning to end users in the search for new ideas [46]. Product inventions in which users are involved are more likely to succeed leading to innovations that the firm would not otherwise have developed [29]. However, systematic evidence is lacking in terms of the impact of user contributions to corporate innovation, when the collaboration with users is most beneficial [29], and how user involvement in the early phase of development should be managed [46].

The literature on the use of customers and users in innovation has either had a strong B2C focus (e.g., [47]) or provided no clear distinction between customers and users. The terms "customer" and "user" are often used interchangeably (e.g., [48–52]). Von Hippel [21] describes users as both firms and individual consumers. Firms are also sometimes referred to as intermediate users [53], although case study reports of intermediate users often refer to individual users, such as physicians [29], surgeons [41], and librarians [54]. In any case, we consider users as those who expect to benefit from using—not selling—a service or product [21,55].

Research on customers and users in innovation in the B2B sector focuses on lead user innovation [40,56–58], user communities [59–62], local or "sticky" information [63–66], and user involvement in innovation processes [29,67,68]. Other literature streams include innovative users [54,69,70] and user entrepreneurship [71–74] . Despite the well-reported benefits, a firm's strong orientation toward its customers and users may have its downside. For example, new technologies may provide opportunities for innovation that do not fit existing customers' and users' needs [75] but may fit the needs of other cohorts, so firms that focus only on their own users and customers may miss the opportunity to acquire new customer bases. Close ties to existing customers may also limit the firm's response to changes in the industry's value networks. Customers and users may also reject radically new innovations if adopting them undermines their existing competencies and requires new capabilities [76,77].

The present study uses the heavy B2B manufacturing industry, which has specific characteristics with respect to its customers and users. First, the industry's customers are not individual consumers but large companies for which our case companies act as suppliers. Second, the supplier firms have close relationships with their key customers, who are responsible for a major share of their sales. According to Bonner and Walker [78], in a B2B context, a relatively small set of customers can influence new product development. Third, the end users do not make purchasing decisions but are typically located within the customer organization or at the customer's customer's organization. To address these characteristics, we concentrate on the distinct roles of customers and users in digital innovation: that is, users

are employees of the customer organization or customers of the customers who work daily with a product.

Leveraging customers and users in the process of digital innovation can be examined from the perspective of how the firms acquire and use their customers' and users' knowledge [79,80]. We use the knowledge-based view of the firm, which is based on the notion that the "critical input in production and primary source of value is knowledge" [79]. Creating and transferring knowledge across a firm's boundaries may help firms exploit new opportunities [81]. Framing our argumentation within the knowledge-based view, we state that acquiring knowledge about customers and users and knowledge obtained from customers and users [26] is critical for organizations to be able to develop digital innovations [82,83]. Therefore, it is important for organizations to build resources and capabilities that will allow them to use these kinds of knowledge [84,85].

A key distinction in the literature related to the knowledge-based view is that between explicit knowledge and tacit knowledge. While explicit knowledge is transmittable in formal, systematic language, such as text, tacit knowledge entails action, commitment, and involvement [86,87]. Tacit knowledge may reside in individuals' plans, skills, and habits, or collectively in the firm's culture, past collaborative experiences, and routines [83,88]. It is acquired by means of personal experience and is difficult to express and observe, whereas explicit knowledge may be observed, articulated, and documented in formal language, print, and electronic media [88,89]. However, tacit knowledge and explicit knowledge should not be seen as dichotomous but as a continuum [88].

We adopt knowledge as a key concept in our study and explore how firms leverage customer knowledge and user knowledge for digital innovation. We look at an industry in which firms are currently adopting digital technologies for product and service innovation to identify ways firms can benefit from customer knowledge and user knowledge in digital innovation processes. More specifically, we seek the links between digital innovation and these kinds of knowledge and identify the methods and challenges of acquiring, distributing, and using it.

Research Context and Methodology

We chose a multiple holistic case study design [90], which is particularly suitable for an exploration of why and how the phenomenon of digital innovation occurs in the context of the cases we chose for our study. Case study research refers to an "empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" [90], such as the topic of the present study. Multiple case studies can lead to generalizable and robust results, as findings have multiple empirical sources [91].

We chose our case companies from the heavy manufacturing industry, a B2B environment. We were interested in companies that produce complex technical products and that are concerned with digital innovation because of its recent diffusion into the industry. This type of industry provides a fruitful setting in which to investigate the emerging practices of digital innovation [5–7]. We also concentrate on B2B companies in order to provide robust findings that are applicable to a specific domain [90].

Our study is comprised of three case companies to which we refer as Company 1, Company 2, and Company 3 for reasons of confidentiality. The companies are all multinational manufacturing companies with headquarters in Europe. The cases were chosen in keeping

with theoretical sampling [91,92] using the criterion of manufacturing companies that are interested in digital innovation. Table 1 presents an overview of the case companies.

We evaluated the firms' attitudes toward and current positions related to digital innovation by reviewing public strategy documents, annual reviews, and public presentations by key innovation and strategy managers, and by means of discussions with firm representatives. The companies differ in terms of the maturity of their digital innovation processes: Company 1 has not yet launched any large-scale digital innovation projects but is experimenting with digital technologies and building a future vision for taking advantage of the opportunities digital innovation offers. Company 2, on the other hand, has chosen digital innovation as a key strategic element, as manifested in its high level of investment in digital innovation projects of significant size and restructuring of innovation practices to support digital innovation processes. Company 3 is involved in digital innovation but is hindered by unresolved challenges related to customers' privacy concerns and access to users. Managers in Company 3 are also concerned that, because of the company's large size, it will not be sufficiently flexible to adapt to the changing needs of the market. They perceive digital innovation in the form of virtual simulation processes as crucial for their product development process, for enhancing their products' digital capabilities—such as those that support maintenance processes—and for creating interfaces between manufacturers and customers with the vision of creating a digital factory.

Company 1 develops a wide range of marine systems and components related to power and propulsion, automation, and control. The company is currently envisioning how to use digital technologies to provide new features for ships, such as remote control, intelligent bridge control, and lower power demand. Their customers include ship companies that own and operate freight, passenger, fishing, and military ships. Users include ship captains and the technical personnel who operate the technologies. Company 2 provides automation and control systems and processing technologies for industrial customers that operate in industries like chemical, oil, pulp and paper, power generation, and mining. Typical users of Company 2 are production plant operators and power plant operators. Company 3's offering is a diverse product portfolio in the B2B sector, ranging from large-scale plants and component technologies to marine systems. The firm's customers are large organizations, and users are employees working in the customers' organizations. Typical users are operators of production plants.

The main data collection method was semi-structured interviews with thirty experts. The interviews with Company 3 were conducted by phone, while those for Company 1 and Company 2 were conducted face-to-face. The interview themes were based on our investigation of the potential of using customer knowledge and user knowledge in developing digital innovations. The first interview guide was open-ended so the research themes could be explored without being structured too tightly. After the first round of interviews, the interview guide was refined to deepen the discussion of emerging topics and to increase the findings' reliability [90]. All interviews were recorded and transcribed verbatim in order to establish a chain of evidence and strengthen the validity of the emerging constructs [90]. Using multiple sources of evidence, such as public strategy documents, annual reviews, and public presentations, to complement the interview data also supported construct validity.

Table 1: The case companies

Company	Company 1	Company 2	Company 3
Field	Marine products	Automation and systems technologies	Plant and component technologies

Size (# of employees)	52,000	16,000	157,000
Location of the unit interviewed	Finland	Finland	Germany
Interviewees' profiles	Design managers, product managers, sales support managers, sales managers, maintenance managers	R&D managers, R&D directors, top managers	R&D managers, innovation managers, IT application support managers
Number of interviews	9	12	9
Length of interviews	49-80 minutes (mean: 63 minutes)	55-143 minutes (mean: 84 minutes)	54-78 minutes (mean: 64 minutes)
Type of interview	Face-to-face	Face-to-face	Telephone

We began the interviews with managers who had a good overview of the innovation activities in the companies. Then we identified employees who are involved with digital innovation in the company. Selecting interviewees in advance based on their departments or job titles was an unsuitable approach for several reasons: Innovation often relies on cross-functional collaboration to reach shared goals [93], and the ownership of digital innovation activities varies from company to company (e.g., between IT and R&D departments) [94]. Furthermore, not all employees in a particular department are knowledgeable about the roles of customers and users in digital innovation. Therefore, we used snowball sampling to identify the appropriate informants [95]. During the interviews with our primary contacts, we asked who would be the best people to talk with about relevant topics, thereby adding new informants to our sample. Snowball sampling is suitable when the study is exploratory in nature [96] and the informants are difficult to identify [97], and the approach has been used successfully in studies on digital innovation [10,19,98]. Data collection was continued until additional data resulted only in minimal new information, that is, until theoretical saturation was reached [96,99].

In Company 1, most of the informants were design managers and design specialists who performed development work but were not in contact with customers or users themselves. Their responsibilities, that is, to renew their product offerings to meet market demand, were similar to those of R&D managers in the other companies. One design manager reported directly to top management and was responsible for gathering customer knowledge via direct customer contact and diffusing the knowledge to the design teams in the business units. Sales managers and sales support managers, who had access to and distributed customer knowledge in the organization, were suggested as potential interviewees, as were maintenance managers, as they were the design teams' most importance source of user knowledge.

In Company 2, most of our data was collected from two R&D teams. The first team focused on hardware, while the second team focused on software. The interviewees, who had titles like R&D manager and R&D director, were suggested based on their wide view of the firm's digital innovation activities. We were also pointed toward employees in R&D who were knowledgeable about customer knowledge or user knowledge. The informants were able to describe the operations of the sales team, the main source of customer knowledge in detail. Members of the sales team were not suggested as interviewees, as they would likely have added only minimal information. Managing user knowledge was integrated into the R&D

teams, which had assigned certain personnel to interact with users. The first couple of interviews revealed that the firm was in the process of implementing a new company-level strategy in which digital innovation is a significant element. This information led us to interview two top managers who were closely involved in formulating the new strategy.

Whereas digital innovation was primarily the R&D/design teams' responsibility in Company 1 and Company 2, the IT department had a bigger role in Company 3. Our primary contact person, a senior IT manager who served as the entry point into the organization, suggested suitable employees who were concerned with digital innovation in the organization, which covered the developed products from the IT and R&D perspectives. R&D teams had some direct contact with customers and users. Similar to Company 2, the informants were able to describe the operations of the sales team in detail and members of the sales team were not suggested as interviewees.

Following a replication logic [90,91], we first used qualitative data analysis programs and a coding scheme deduced from the interview guide to analyze each case individually. The research team members discussed the findings of each case, and emergent topics led to an iteration of the coding scheme. With this updated coding scheme, we analyzed each case again. The coded data formed the base for cross-case analyses, during which we revisited the data in an iterative process and collected emerging findings into tables. Thus, the analysis process focused on matching patterns across the cases and building explanations for what occurred in the data, thereby increasing the research's internal validity [90].

Our interviewees explained how they perceive digital innovation in their companies and industries, and their views were in line with extant studies on the topic (e.g. [5]). According to the interviewees, digital innovation is driven in their industry by the emergence of new digital technologies and the adoption of existing digital technologies from other sectors (e.g., consumer products). Their view is that new digital technologies promote innovation by creating new opportunities for innovation and by facilitating R&D work. This division supports Nambisan's distinction in the role of IT as *making new innovation outcomes* possible and *facilitating the innovation process* [1].

For our case companies, the relevant digital technologies for new digital innovation outcomes include the Internet of Things, big data, sensor technologies, cloud computing, machine-machine interaction, and GPS. Those mentioned in the category of new digital technologies that facilitate R&D work include new digital tools and methods to help R&D and production, such as 3D tools, engineering applications, communication technologies, and 3D printing and scanning. We decided to focus on the first category, digital technologies for new digital innovation outcomes, as it is more relevant to our framework, which emphasizes innovation's variance-creation as a key activity in responding to disruptive technologies [36].

The interviewees suggested that digital technologies create two kinds of opportunities for innovation: incremental innovation, in which existing products and services are improved, and radical innovation, in which significantly novel products and services are developed. Integrating new technologies like sensors into existing products and services provides possibilities for optimizing their use and improving productivity through incremental innovation. On the other hand, most of the interviewees predicted that novel concepts based on new digital technologies would transform their industry significantly. Radical digital innovations could change the industry's business models, create major leaps in performance, and/or transform how the products are used. We discovered that, for our case companies, the limiting factors for exploiting digitization by means of digital innovation are not in

technological capabilities, as those could be developed or sourced easily, but uncertainties about future market needs and choosing the right trajectories for developing digital innovations. Informants from all companies described their industry as conservative and slow to change, but they predicted that digital technologies would bring about dramatic changes in how their products and services are used in the future. This combination of long product life cycles, pressure to engage in digital innovation, and lack of specific innovation goals poses a major managerial challenge. The development of more radical products and services in particular requires substantial investments in the industry and is not likely to take place without a clear vision of the future.

The case companies had similar views about how digital technologies could be used for digital innovation. All of them manufacture physical components and systems for complex industrial products and facilities, such as marine vehicles and power plants. New opportunities arise when physical components are combined with digital technologies like sensors and RFID tags so these components can sense changes in their environment. Innovation potential is related to connecting these components to a network and gathering and analyzing the massive amounts of data they sense in order to, for example, optimize a power plant's or a production facility's operations at a significantly higher level than was previously possible. Other opportunities are related to control systems, such as how to design control interfaces that take advantage of the increased amount of data collected from the sensors. The technologies also enable new kinds of services, such as intelligent maintenance services that anticipate future maintenance needs in detail and big data analysis services.

Findings

Our findings are divided into, first, a discussion of how our interviewees perceived their customers and users and the value for digital innovation they saw in interacting with them. Second, we discuss and classify the practices the companies use in interacting with users and customers. Our key results in terms of the differences between customer knowledge and user knowledge in digital innovation are collected in Table 2.

From Customers to Users

Early in our analysis, we noticed the need for a clear distinction between customers and users. All three of our case firms operate in B2B environments. End users of the products use the products directly but do not make the buying decisions, as distinguished from customers, who make the buying decisions but do not use the products directly. In addition, because the developed products are heavy industrial components and systems and the end users are in the customers' organizations or farther down the supply chain in the customer's customer's organization, neither the customers nor the users much resemble their counterparts in the consumer industry.

For our case companies, the customers' and users' roles in guiding the innovation processes differ. As one interviewee from Company 3 explained,

> We innovate new products for our customers for use in our customers' products, which are then used by the end user. That means we have to innovate, on one hand, based on the specifications from our customers .... On the other hand, we have to anticipate which trends are there for the end user, how the end user uses our product, and how he [or she] perceives it. [Those two sides go] hand in hand.
> (Interviewee in Company 3)

The informants perceived users as individuals who work in a specific environment, such as the operators of marine vehicles and power plants. Because the number of accessible users is low, decision-making based on collectives of users is difficult. Moreover, the firms concentrated on acquiring tacit knowledge from the users, which is typically difficult to separate from personal feelings, habits, and experiences [83]. Therefore, the interviewees saw understanding users as individuals as beneficial in decision-making.

However, the concept of a customer was more ambiguous. The interviewees described interacting with customers as dealing with a "stream of opinions" from multiple sources. They were not able to point out customers at an individual level since buying decisions are made collectively:

> You have, of course, the problem that one customer is [actually] a community of many people …. There is not only one opinion, but streams [of opinions]. (Interviewee in Company 3)

The interviewees perceived customers and users as knowledge sources that could help guide the digital innovation process and its goals. They emphasized the importance of customer knowledge and user knowledge for digital innovation because they saw the diffusion of digital technologies' leading to changes in market needs, and they are looking for ways to create goals for digital innovation in situations where there are no clear development trajectories.

The interviewees saw a significant challenge in developing digital innovations because of the rapid pace of change in market needs that results from customer organizations' adoption of new digital technologies. The customers and users reported having been exposed to new digital technologies in other parts of their lives (e.g., consumer electronics) and being accustomed to certain functionalities and levels of usability. The interviewees emphasized the increasing need for their organizations to be flexible. Company 2 recently adopted agile development processes in response to this challenge:

> The rapidly developing technologies for consumer products are clearly starting to influence the manufacturing industry. To respond, we need to increase the pace of our product development cycles so we can offer new features when there's strong hype on certain technologies, instead of five years too late. (Interviewee in Company 2)

Most of the interviewees acquired their knowledge about adapting to rapid, short-term changes from their customers. Customer knowledge is related to the customer's purchasing decision, that is, whether the firm would buy a product or a service and what factors influence their decision. This knowledge is related to improvement suggestions and performance needs, as the knowledge is typically articulated in terms of requirements lists, which include both technical and commercial aspects of their requirements. Interviewees in all three case firms described their customers as conservative entities that focus almost solely on price, product performance, and product reliability. Much of the customer knowledge concerns incremental improvement suggestions, knowledge of malfunctions and problems with the products, and new industry standards and requirements that must be included in the product specifications.

However, the interviewees reported that customers are often unable to express their needs beyond short-term improvements and adjustments, and since they cannot specify their expectations for digital innovation, setting long-term goals is difficult. They are somewhat

knowledgeable about the new technologies but cannot comprehend all the opportunities that they create. Nevertheless, it was the interviewees' view that both the case firms and their customers see the effects of new digital technologies as unavoidable and significant, despite having a difficult time describing their content and impact in detail, apart from identifying related technologies. In summary, customer knowledge is available in explicit form, it guides digital innovation processes to adapt to short-term changes in market needs, but it does not help in setting long-term development goals.

> The big trend is obvious, but everyone has his [or her] own way of approaching digitization. Like our competitors, we have identified the general direction of where the industry is going, and we need to show our customers that we are involved in this. (Interviewee in Company 2)

Not finding long-term goals for innovation in customer knowledge, our case companies turned to their products' end users. At one time, the users had been of interest primarily to user-interface designers, but the interviewees reported that now R&D managers seek guidance in navigating in the new opportunity space by understanding the users and their work. User knowledge is employed not only to help improve existing products but also to enable radical innovations by providing guidelines in setting long-term development goals. Categories of user knowledge that are relevant to our case firms include understanding the user experience, feelings, and emotions; usability; and the context of use. This knowledge is often tacit, that is, it is not codified, so it is difficult to share in written form. According to the interviewees, R&D employees seek tacit user knowledge to understand how their products are used in practice, what constitutes the core of the users' work, and how their work processes can be improved. The innovation teams are also interested in explicit user knowledge in the form of usage data, but they have found that the customers are not willing to provide data for fear of losing competitive advantage. The customers inevitably have some level of user knowledge at their disposal, but the suppliers—that is, our case companies—have stronger incentives than their customers do to acquire in-depth user knowledge. There may also be time delay and information loss in transferring user knowledge to customers and then to suppliers. Our informants suggested that there is value in involving users directly into digital innovation processes instead of going through customers:

> I believe that these new digital technologies will transform our industry in the next ten years. We are currently looking at the users and trying to understand their work: goals, tasks, and experiences that are independent of tools or technologies. In this way we can find seeds for radical innovations. Otherwise, we're likely to be constrained to existing tools. (Interviewee in Company 2)

Our interviewees saw knowledge of the user experience as important because digital innovation can bring major changes to work practices and because new digital technologies make possible significant increases in the amount of data and information available to support the work. Knowledge about the user experience can be used to filter and compress the data so it is useful and manageable. Many new digital products are based on collecting and analyzing massive amounts of data, so product designers must understand how the data is relevant to the end user and which parts of the data are relevant.

The firms face several challenges in acquiring user knowledge. The R&D employees are not free to contact the users directly but are represented in this effort by the sales organizations that are responsible for managing the customer interface. However, the sales organizations do not consider arranging meetings with the end user a high-priority task. For their part,

customers will contribute the time and effort required to arrange meeting between suppliers and users only if they perceive immediate value from doing so. As a result, they seldom make it happen:

> It's not easy to convince a customer to allow you to see how the products are used in practice. We need a lot of knowledge, and all knowledge we get is filtered by the customer. (Interviewee in Company 3)

Another issue that arises from the distinction between customers and users concerns customer organizations' ability to adopt novel innovations. Although one of the case firms can develop new solutions based on new digital technologies and in-depth understanding of users' needs, the interviewees in that firm reported experiencing significant difficulty in convincing customers of the value of the new innovations:

> The basic needs of the customers are very clear. The challenge is to show that new services are, without doubt, worth the cost and not merely nice additional features. (Interviewee in Company 2)

Table 2: Differences between Customer Knowledge and User Knowledge

	Customers	**Users**
Type of knowledge	Mostly explicit	Mostly tacit
Knowledge sources	Distributed	Individuals
Guidance for innovation	Short-term changes in market needs	Long-term vision for digital innovation
Innovation goals	Mostly incremental improvement of existing products and services	Introducing radically new products and services and improving existing ones
Examples of knowledge categories	Feedback on ongoing projects, improvement suggestions, problems with existing products, new industry requirements	Usability, user experience, understanding work contexts and practices, future needs
Methods to acquire knowledge	Feedback meetings, management meetings, sales meetings	On-site user studies, use of front-line employees, prototyping
Methods to distribute knowledge	IT systems	User-insight workshops, informal cross-functional interactions
Methods to use knowledge	Product specification lists, roadmaps	Internal scenario work, collaborative research projects
Challenges	Convincing customers of the value of new innovations; rapid pace of changes in needs	Difficulty in contacting end users; restricted access to usage data because of privacy concerns

Practices Related to Customer Knowledge and User Knowledge

This section introduces twelve practices that the three case companies use to integrate customer knowledge and user knowledge into their processes of developing digital innovations. After discussing practices that relate to acquiring customer knowledge and user knowledge, we discuss practices for distributing and using tacit user knowledge. We collect our results on the practices in Table 3.

Acquiring customer knowledge and user knowledge. We find that the practices our case companies use to acquire customer knowledge differ from those they use to acquire user knowledge.

Customer knowledge consists of requirements for new products and services and information about problems with existing ones, so it is mostly in explicit form. It is acquired through meetings with representatives at various levels of the customer's organization. An important source of customer knowledge is sales meetings organized by the key account organization (or similar) in the innovator firm, the purpose of which is to learn about changes in the customer firm's needs. Interaction is frequent, especially with important customers:

> A B2B customer will always come to you with requirements. That customer will be able to say precisely what the functionality needs to be. (Interviewee in Company 3)

> Our sales persons have discussions with important customers daily. The customers follow how regulations develop in their industry and what kinds of new standards and legislation are coming. (Interviewee in Company 2)

In addition to sales meetings, management-level development meetings are conducted occasionally with the goal of identifying the customer's overall goals and trends and future challenges that may need to be addressed:

> We do have regular exchanges with our customers on the operator level, but also in management development meetings, where we discuss on the management level new development topics. (Interviewee in Company 3)

Customers also provide feedback in the course of innovation projects. They are shown new functionalities before the products are built in order to use their knowledge in steering the direction of development. Feedback includes also discussions of current products and implications for future development:

> [We discuss] the feedback on the product we delivered: what is good, what is bad, what could be improved, what have been weaknesses of our delivered products. (Interviewee in Company 3)

Unlike customer knowledge, user knowledge consists of understanding the user experience and users' work context, views on usability, and future needs, so it is mostly in tacit form, which is difficult to identify and transfer. We identified three practices the case companies employ to gather user knowledge: prototyping, use of frontline employees, and on-site user studies. Although our informants perceived users as individuals, knowledge about these individual users is accumulated in the knowledge acquisition and subsequent steps.

The interviewees reported that they use prototypes as a tool to experiment with new ideas. By presenting users with concept drafts and tangible prototypes, they encourage users to think about how the new features will affect their work. Prototypes are also used in triggering

discussions with customers, but the interviewees indicated that showing prototypes to users is more valuable in creating a long-term vision for digital innovation than is showing them to customers, where the feedback tends to focus on whether the new ideas will help the customers reach short-term goals and meet existing performance goals:

> We take prototypes with us to the workplace and discuss what kind of operating situations they would make easier. These discussions have a strong future orientation. (Interviewee in Company 2)

In the B2B context, users are often within the customer organization and are not easily accessible to the innovator/supplier firms. Our case companies often use their own employees to get a user perspective without involving the actual end users:

> We have no direct access to external users. If we need access, we have to go via our colleagues responsible for contracts in engineering. (Interviewee in Company 3)

R&D often employs front-line employees in its own company who have spent time with end users and thus are able to relate to them to provide valuable insights about users' needs without involving users from the customer organization. The R&D teams also get insights about users' needs from new recruits in their own companies who have work experience in positions similar to those of the end users:

> [It is] the maintenance staff that meets the users … and has the best contact with the users. They have the best knowledge of the actual situations. (Interviewee in Company 1)

> [We] have many specialists who know their systems but are not fully aware of how their systems are operated later on. They just have their isolated view on their own work. To have a more general overview, we try to employ former [users] if we can. (Interviewee in Company 3)

A third practice for acquiring tacit user knowledge is that of conducting on-site user studies to observe their work and interview them at the "feelings" level in order to gain empathy with them:

> I have been travelling around [the user sites] and taken the younger colleagues with me…. There is a lot of knowledge that is not written anywhere, and you can understand the meaning better from gestures than from written words. (Interviewee in Company 1)

> We sit down with the users at their workplaces. We ask how they work and try to understand it and get the feel of their work. We have some good examples of when the users have spontaneously started to tell us about the stress and tension they feel in their jobs. (Interviewee in Company 2)

Table 3: Practices Related to Customer Knowledge and User Knowledge

Category	From	Practice	Description	Purpose	Type of knowledge	Companies
Acquiring knowledge	Customers	Feedback meetings	Meetings with customers mid-project to evaluate progress and confirm direction.	Gathering feedback from customers on works in progress.	More explicit	3
		Sales meetings	Ongoing discussions with customers to keep up with their changing needs.	Learning about new product requirements and problems with existing products.	More explicit	1, 2, 3
		Management meetings	Regular meetings with important customers' management.	Understanding the customer's big picture and long-term goals.	More explicit	1, 3
	Users	Use of front-line employees	Using maintenance staff and field service engineers as knowledge sources; hiring R&D employees with user backgrounds.	Understanding workflows and the usability of current products without involving the users themselves.	More tacit	1, 2, 3
		On-site user studies	Visiting users at their workplaces; interviewing and observing the users.	Empathizing with users; identifying latent user needs; understanding work	More tacit	1, 2, 3

				context and work practices.		
		Prototyping	Demonstrating new concepts with tangible prototypes.	Demonstrating and discussing novel products and features.	More tacit	2
Distributing knowledge	Customers	IT systems	Updating new customer knowledge into, for example, a CRM system.	Bringing relevant parties up to date on changes in customer requirements.	More explicit	1, 2, 3
	Users	User-insight workshops	Regular internal workshops to disseminate user knowledge throughout the company.	Making the most of the limited access to user knowledge; sharing information about users.	More tacit	3
		Informal cross-functional interactions	Encouragement for ad hoc discussions; open cross-functional workspaces.	Promoting the sharing of user knowledge across organizational functions.	More tacit	1, 2
Using knowledge	Customers	Product specification lists and roadmaps	Compiling customer requirements and user requirements into specification lists.	Setting goals for new development projects.	More explicit	1, 2, 3

Users	Internal scenario work	Building future scenarios that describe trends and future use cases.	Creating explicit goals and vision based on tacit user knowledge.	More tacit	2, 3
	Collaborative research projects	Future-oriented research projects with research institutes and other firms on technologies and ways of working.	Leveraging external organizations to help envision future scenarios.	More tacit	1, 2

Distributing customer knowledge and user knowledge. As customer knowledge is usually explicit and easily transferable, the companies can use IT systems like Customer Relationship Management (CRM) systems to distribute the latest knowledge about customers' needs. However, the R&D teams rarely access the CRM systems themselves; they tend to be used by the firms' sales and sales support teams. We found that personal face-to-face meetings and discussions, not IT systems, are used to distribute user knowledge. The interviewees considered distributing knowledge about users and their work throughout the R&D units to be important in guiding R&D employees in their everyday decisions:

> Operative R&D employees make lots of small decisions based on how they comprehend the users. We've made drastic mistakes in our product designs that would have been avoided by spending a little time with the users. (Interviewee in Company 2)

Because of the limited access to users and the resources needed for acquiring user knowledge, the companies adopted practices to distribute acquired user knowledge. In Company 2 telling stories about users that are accompanied by drawings and photographs was highlighted as a good way to transfer user knowledge. Company 3 uses regular user-insight workshops to disseminate user knowledge throughout the organization. Company 3's interviewees said that user knowledge must be actively distributed because direct access to it is limited. The workshops are usually organized after users have been visited for purposes like testing new products with them.

> About the workshops: words, discussions are the most important methods. (Interviewee in Company 3)

Company 1 and Company 2 also encourage their employees to engage in informal interactions and discussions about users across functional lines. Company 2 moved the product development staff to a single open workspace where R&D managers, R&D employees, product managers, and others are located in order to advance the diffusion of user knowledge and generate fertile ad hoc discussions:

> The layout of our R&D space is one thing that has promoted innovation and helped reach user experience goals. We have one space with a few big areas without any privacy screens. We just have tables in different formations. R&D employees, specificators, business representatives (such as product managers), and R&D managers are all in the same space. Spontaneous ad hoc conversations are especially encouraged. (Interviewee in Company 2)

Using customer knowledge and user knowledge. Finally, we identified practices for using customer knowledge and user knowledge for digital innovation. The widespread impression among our interviewees was that their customers have difficulty envisioning their long-term needs and wishes as they relate to digital innovation, so customer knowledge is not readily available for purposes with long-term future orientations. Those purposes rely heavily on tacit user knowledge instead. However, customer knowledge does provide guidelines for the near future and for guiding short-term development, such as product specification lists. Customer knowledge may also be particularly applicable for short-term purposes because it is available in explicit form and can be used straightforwardly. The case firms collect customers' needs and

wishes into requirements lists and sometimes launch innovation projects based on the needs of a single large customer. In other cases, the firms develop innovation roadmaps based on the requirements lists and launch new projects according to the roadmaps:

> Ideas go to R&D groups for evaluation. The groups have product management and businesspersons. Requirement specifications govern the development to a large extent. The requirement specifications come from business, that is, people who have discussions with our key customers daily. We get information about norms and standards, etc. This kind of information is put together into business requirements lists. Then the business prioritizes them, and roadmaps are created based on them, or existing roadmaps are updated. New development projects are launched based on the roadmaps. (Interviewee in Company 2)

One use the companies have identified for tacit user knowledge is to create explicit goals for digital innovation based on that knowledge. The case companies use scenario work and research projects to determine directions for digital innovation, as building future scenarios is a key practice for explicating tacit knowledge about users and tacit user knowledge is based on a deep understanding individual users. The scenarios picture future use cases and describe ongoing trends in order to explain users to a larger audience and set long-term user experience goals for the development of digital innovations. The scenarios allow the companies to forecast in which direction customer needs will develop in the long-term even though the customers themselves are unable to convey their needs that far in the future. Making R&D employees aware of the scenarios also helps them make better daily design decisions:

> We need to know the technical and operational trends, how the [users] of tomorrow will operate, and what the technical needs they have for these [products] will be. It is, of course, a bit tricky to forecast how the situation will be in ten to fifteen years because our product life cycle is very long, but it is important to forecast what will happen in ten years and to be prepared for that. (Interviewee in Company 3)

> We try to visualize what the potential value for the customer would be, what the customers could be interested in. It's mostly based on new functionalities. We aren't interested in numbers until later stages, when we are thinking of launching R&D projects. (Interviewee in Company 2)

Company 1 and Company 2 also use collaborative research projects to complement their internal scenario work. The research projects are carried out with research institutes and other firms in order to help firms comprehend the perspectives of future users and their work and how upcoming new technologies will influence them.

> In all of the research projects, we try to sketch radically new ways of working using new technologies. New technologies overcome lots of the limitations that currently determine how the user does his [or her] work. We try to picture how our users would work in the [distant] future and what kinds of user experience goals we could set. (Interviewee in Company 2)

> Research projects with universities and other research units are very important for us. These are usually the fastest ways to work with radically new ideas and to search user-driven opportunities for future offerings. (Interviewee in Company 1)

Discussion

Prior literature has acknowledged the innovation potential of new digital technologies for the manufacturing industry [3,5–8], but little is known about how manufacturing firms should manage their digital innovation processes [2,4,17]. We grounded our observations in data from a multi-case study with three multi-national organizations that face the diffusion of digital technologies as an industry-level disruption. We adopted the knowledge-based view framework, which emphasizes the management of various types of knowledge in developing innovations [79,80,100], and focused on how the firms leverage customer knowledge and user knowledge for use in digital innovation.

Our findings contribute to the literature on digital innovation in three ways. First, we propose that identifying changes in market needs is a twofold challenge for digital innovation processes in the B2B manufacturing industry. Second, we identify the roles of customers and users in guiding these processes and we observe differences in the nature and content of relevant customer knowledge and user knowledge. Third, we identify practices for leveraging customer knowledge and user knowledge in digital innovation and provide managerial implications.

Reactive and proactive management of digital innovation in the B2B manufacturing industry

Our first contribution addresses the challenges inherent in understanding market needs and their evolution when developing digital innovations in the B2B manufacturing industry [21]. We identified two distinct challenges: the need for companies to be able to react to changing market requirements, and the need for companies to propose new solutions proactively based on new digital technologies. We also argue that the second challenge is likely to be significantly more demanding because of the characteristics of the B2B manufacturing industry.

Our findings suggest that the pace of change in market needs has increased because of advances in digital technologies and their ongoing diffusion from other industries to the manufacturing industry. Manufacturers must improve their offerings to meet new industry standards and suggestions from their customers. Pressure to react to emerging needs has led companies to become more flexible by, for example, shortening their product development cycles by adopting agile development processes. To keep up with the changing needs of the market, companies must have systematic ways to integrate knowledge about their environment into their development processes [32,33].

Merely reacting to customer needs is not likely to lead to making good use of the opportunities that new digital technologies provide [2,4]; instead, a proactive approach, where companies drive change by developing new digital innovations and offering them to their customers, is required. Managing uncertainties about future market needs is the focal challenge of this proactive approach. It has often been proposed that companies should conduct experimentations to test market responses to new technologies in the early stages of the innovation process, thereby

reducing uncertainty [37]. Experimentation and associated iterative innovation processes are especially suitable for digital innovations [1,16,18,38,39,94,101].

The B2B manufacturing industry has characteristics that influence how companies benefit from the reactive and proactive approaches. Despite some increase in the pace of change in market needs related to digital technologies, the overall industry dynamics tend to be stable. Customers are considered to be conservative, valuing reliability and cost-effectiveness, and unwilling to take risks with novel innovations. With manufactured products like power plants and ships, the product life cycles may span multiple decades. New products are significant investments for the customers, as is their development for the manufacturer. Because of these characteristics and the tendency for changes in market demand to require small-scale improvements, the reactive approach to digital innovation is often appropriate. For the same reasons, the proactive approach is challenging, as experimenting with innovations (as the literature has proposed) is not often practicable. While such experiments may work well for small-scale features, radical breakaways from current offerings are likely to be costly to develop, and testing their market potential is likely to run into skeptical, conservative customers. Hence, we find a mismatch between the rapid pace of digital technologies' development and the slow movement of the industry [19]. To overcome this challenge, the companies we investigated rely on planning instead of experimenting. They seek to understand their markets in a way that allows them to reduce uncertainties and pursue a long-term direction to guide their digital innovation processes. Thus, our findings suggest that, to benefit from the changes new digital technologies bring to the manufacturing industry, companies must be flexible in the short-term and find new ways to set a long-term direction for digital innovation.

Distinct roles of customers and users

We find that customers and users have distinct contributions to firms' ability to respond to the challenge of identifying market needs. Customers, who are responsible for making the purchasing decisions related to new innovations but who do not use the products and services themselves, are an important source of knowledge related to changes in short-term requirements regarding the functions, properties, constraints, and rationale according to which new products and services should be designed [102]. However, since customers cannot provide guidance for digital innovation beyond expressing their immediate needs, their input is restricted in large part to guiding incremental improvements in existing products and services. Their difficulty in expressing their long-term future needs derives from the fact that the diffusion of digital technologies has created a wide new opportunity space where dominant trajectories for future development have not yet been established. In short, customer knowledge is important in responding to short-term changes in market needs but does not help in setting long-term guidelines for digital innovation.

Instead of focusing on customers for their long-term innovation goals, the supplier firms we investigated focus on users. Because of the low numbers of users and limited access to collective data about them, the companies had to find ways to understand their individual users and derive their needs from that understanding. By understanding their users' latent needs and the users' work context, they can envision future users' needs and usability criteria for new digital products and services. Our findings suggest that, to respond to the opportunities and challenges created by

the diffusion of digital technologies [36], such supplier firms should find ways to integrate user knowledge into their digital innovation processes, as focusing solely on customers' needs may limit the firm's ability to innovate proactively—that is, beyond incremental improvements in current products and services [103,104]. It is user knowledge that facilitates the radical innovations that create new trajectories for future developments [37]. This finding supports earlier research that sees users as especially valuable in radical innovation [29]. Based on our findings, we emphasize the need to distinguish customers and users, a distinction that has been lacking in the extant literature [48,49,51,52]. In the B2B manufacturing industry context of our study, customers and users are associated with different types of knowledge, management practices, challenges, and contributions to digital innovation processes (Table 2).

Managing customer knowledge and user knowledge

According to the knowledge-based view of the firm, managing different types of knowledge requires different practices [79]. Our findings support this view by distinguishing between practices used mainly for managing explicit customer knowledge and those that deal primarily with tacit user knowledge (Table 3). Our study contributes to the literature on the knowledge-based view of the firm by identifying twelve knowledge-management practices that we categorize according to the type of knowledge [83,88]. In the context of our study, customer knowledge is usually provided in explicit form, and the case firms are experienced in acquiring it and in integrating it into the specifications of new innovation projects. However, the user knowledge that is available to the firms we study is usually in tacit form, embedded in the users and their work practices and, therefore, difficult to express and transfer. In order to create long-term goals for digital innovation, the firms adopt new methods for acquiring, disseminating, and using this kind of tacit knowledge. We argue that it may be beneficial for B2B manufacturing companies to adopt these kinds of practices for managing tacit knowledge in promoting their digital innovation processes. Tacit knowledge may help them set long-term goals when no suitable explicit knowledge is available. The identified practices also add to the literature on customer and user involvement in innovation by providing practical guidelines for managing the integration of external knowledge into the innovation process and describing open innovation activities in the context of the B2B manufacturing industry [21,21,23].

Practical implications

Managers in the B2B manufacturing industry face an interesting situation where their customers expect them to be involved in digital innovation. At the same time, the customers fail to provide proper guidance on their needs and are conservative when it comes to digital breakthroughs. These B2B manufacturing companies may want to make arrangements, such as "digital innovation labs," where they can explore new digital technologies with users in a controlled environment. Interacting with users may help them reduce uncertainties about the future, while separate structures, decoupled from the regular business, provide an environment for continuous learning, building capabilities in new digital technologies, and developing innovations based on them. Users provide guidance in choosing which capabilities and which kinds of innovations should be developed. Arrangements of this type also make it possible to showcase to customers new ideas and concepts and to demonstrate to them that the company is involved in digital innovation. Then, when new capabilities reach maturity, the digital innovations may be

integrated into the daily business. Such arrangements have three benefits: a) interacting with users can unveil customers' future needs, b) proficiency in digital innovation and digital technologies can be built without disturbing the daily business, and c) the company can demonstrate its involvement in digital innovation without yet having digital technologies in its product portfolio.

Conclusion

The diffusion of digital technologies creates new opportunities but brings with it uncertainties about the future. This article suggests two ways that B2B manufacturing companies can leverage customer knowledge and user knowledge to guide digital innovation processes. Customers can provide explicit knowledge on how the diffusion of digital technologies changes their short-term needs, and frequent interactions with key customers can help firms develop incremental improvements in existing products and services, while tacit user knowledge can make possible the creation of long-term goals for digital innovation. Since customers cannot help manufacturing companies find the right directions in which to develop digital innovations beyond the short-term, companies should seek in-depth understanding of their products' end users in order to create long-term goals for digital innovation. For this purpose, firms must adopt new methods of acquiring, distributing, and using tacit user knowledge.

Acknowledgements

We gratefully acknowledge financial support by Tekes – the Finnish Funding Agency for Innovation, the Otto A. Malm Foundation, and Airbus Operations GmbH. We further would like to acknowledge the fruitful discussions with Walter Brenner.

References

[1] S. Nambisan, Information Technology and Product/Service Innovation: A Brief Assessment and Some Suggestions for Future Research, J. Assoc. Inf. Syst. 14 (2013) 215–226.
[2] D. Nylén, J. Holmström, Digital innovation strategy: A framework for diagnosing and improving digital product and service innovation, Bus. Horiz. 58 (2015) 57–67.
[3] Y. Yoo, R.J. Boland, K. Lyytinen, A. Majchrzak, Organizing for Innovation in the Digitized World, Organ. Sci. 23 (2012) 1398–1408.
[4] Y. Yoo, Computing in Everyday Life: A Call for Research on Experiential Computing, MIS Q. 34 (2010) 213–231.
[5] D.H. Lasi, P.D.P. Fettke, P.D.H.-G. Kemper, D.-I.T. Feld, D.-H.M. Hoffmann, Industry 4.0, Bus. Inf. Syst. Eng. 6 (2014) 239–242.
[6] A. Radziwon, A. Bilberg, M. Bogers, E.S. Madsen, The Smart Factory: Exploring Adaptive and Flexible Manufacturing Solutions, Procedia Eng. 69 (2014) 1184–1190.
[7] X. Xu, From cloud computing to cloud manufacturing, Robot. Comput.-Integr. Manuf. 28 (2012) 75–86.
[8] Y. Yoo, The Tables Have Turned: How Can the Information Systems Field Contribute to Technology and Innovation Management Research?, J. Assoc. Inf. Syst. 14 (2013) 227–236.

[9] M.J. Benner, Securities Analysts and Incumbent Response to Radical Technological Change: Evidence from Digital Photography and Internet Telephony, Organ. Sci. 21 (2010) 42–62.
[10] J., Richard J. Boland, K. Lyytinen, Youngjin Yoo, Wakes of Innovation in Project Networks: The Case of Digital 3-D Representations in Architecture, Engineering, and Construction, Organ. Sci. 18 (2007) 631–647.
[11] K. Lyytinen, G.M. Rose, The Disruptive Nature of Information Technology Innovations: The Case of Internet Computing in Systems Development Organizations, MIS Q. 27 (2003) 557–595.
[12] M. Tripsas, Technology, Identity, and Inertia Through the Lens of "The Digital Photography Company," Organ. Sci. 20 (2009) 441–460.
[13] D.E. Bailey, P.M. Leonardi, S.R. Barley, The Lure of the Virtual, Organ. Sci. 23 (2011) 1485–1504.
[14] D. Dougherty, D.D. Dunne, Digital Science and Knowledge Boundaries in Complex Innovation, Organ. Sci. 23 (2011) 1467–1484.
[15] S. Nambisan, Information Systems as a Reference Discipline for New Product Development, MIS Q. 27 (2003) 1–18.
[16] R.G. Fichman, B.L. Dos Santos, Z. (Eric) Zheng, Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum, MIS Q. 38 (2014) 329–A15.
[17] Y. Yoo, O. Henfridsson, K. Lyytinen, Research Commentary—The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research, Inf. Syst. Res. 21 (2010) 724–735.
[18] Y. Yoo, K.J. Lyytinen, R.J. Boland, N. Berente, The Next Wave of Digital Innovation: Opportunities and Challenges: A Report on the Research Workshop "Digital Challenges in Innovation Research," Social Science Research Network, Rochester, NY, 2010.
[19] O. Henfridsson, L. Mathiassen, F. Svahn, Managing technological change in the digital age: the role of architectural frames, J. Inf. Technol. 29 (2014) 27–43.
[20] F. Svahn, O. Henfridsson, The Dual Regimes of Digital Innovation Management, in: 2012 45th Hawaii Int. Conf. Syst. Sci. HICSS, 2012: pp. 3347–3356.
[21] E. von Hippel, Democratizing Innovation, MIT Press, Cambridge, Massachusetts, 2005.
[22] A.L.M. Cavaye, User participation in system development revisited, Inf. Manage. 28 (1995) 311–323.
[23] O. Gassmann, P. Sandmeier, C.H. Wecht, Extreme customer innovation in the front-end: learning from a new software paradigm, Int. J. Technol. Manag. 33 (2006) 46–66.
[24] A.W. Joshi, S. Sharma, Customer Knowledge Development: Antecedents and Impact on New Product Performance, J. Mark. 68 (2004) 47–59.
[25] M.L. Markus, J.-Y. Mao, Participation in Development and Implementation - Updating An Old, Tired Concept for Today's IS Contexts, J. Assoc. Inf. Syst. 5 (2004) 514–544.
[26] F. Khodakarami, Y.E. Chan, Exploring the role of customer relationship management (CRM) systems in customer knowledge creation, Inf. Manage. 51 (2014) 27–42.
[27] M. Gibbert, M. Leibold, G. Probst, Five Styles of Customer Knowledge Management, and How Smart Companies Use Them To Create Value, Eur. Manag. J. 20 (2002) 459–469.
[28] C. Lettl, C. Herstatt, H.G. Gemuenden, Users' contributions to radical innovation: evidence from four cases in the field of medical equipment technology, RD Manag. 36 (2006) 251–272.

[29] A.K. Chatterji, K.R. Fabrizio, Using users: When does external knowledge enhance corporate product innovation?, Strateg. Manag. J. 35 (2014) 1427–1445.
[30] M.W. Johnson, C.M. Christensen, H. Kagermann, Reinventing Your Business Model, Harv. Bus. Rev. 86 (2008) 50–59.
[31] H.C. Lucas Jr., J.M. Goh, Disruptive technology: How Kodak missed the digital photography revolution, J. Strateg. Inf. Syst. 18 (2009) 46–55.
[32] K.M. Eisenhardt, J.A. Martin, Dynamic capabilities: what are they?, Strateg. Manag. J. 21 (2000) 1105–1121.
[33] D.J. Teece, G. Pisano, A. Shuen, Dynamic Capabilities and Strategic Management, Strateg. Manag. J. 18 (1997) 509–533.
[34] C.M. Christensen, The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail, Harvard Business Press, 1997.
[35] M.L. Tushman, P. Anderson, Technological Discontinuities and Organizational Environments, Adm. Sci. Q. 31 (1986) 439–465.
[36] P. Anderson, M.L. Tushman, Technological Discontinuities and Dominant Designs: A Cyclical Model of Technological Change, Adm. Sci. Q. 35 (1990) 604–633.
[37] J. Bessant, R. Lamming, H. Noke, W. Phillips, Managing innovation beyond the steady state, Technovation. 25 (2005) 1366–1376.
[38] J. Highsmith, A. Cockburn, Agile software development: the business of innovation, Computer. 34 (2001) 120–127.
[39] R. Vidgen, X. Wang, Coevolving Systems and the Organization of Agile Software Development, Inf. Syst. Res. 20 (2009) 355–376.
[40] E. von Hippel, Lead Users: A Source of Novel Product Concepts, Manag. Sci. 32 (1986) 791–805.
[41] C. Lettl, User involvement competence for radical innovation, J. Eng. Technol. Manag. 24 (2007) 53–75.
[42] W.E. Baker, J.M. Sinkula, Does Market Orientation Facilitate Balanced Innovation Programs? An Organizational Learning Perspective, J. Prod. Innov. Manag. 24 (2007) 316–334.
[43] B.J. Jaworski, A.K. Kohli, Market orientation: Antecedents and consequences, J. Mark. 57 (1993) 53–70.
[44] B. Fitzgerald, The Transformation of Open Source Software, MIS Q. 30 (2006) 587–598.
[45] H. Holmström, O. Henfridsson, Improving Packaged Software through Online Community Knowledge, Scand. J. Inf. Syst. 18 (2006) 3–36.
[46] P.R. Magnusson, Exploring the Contributions of Involving Ordinary Users in Ideation of Technology-Based Services, J. Prod. Innov. Manag. 26 (2009) 578–593.
[47] B. Edvardsson, P. Kristensson, P. Magnusson, E. Sundström, Customer integration within service development—A review of methods and an analysis of insitu and exsitu contributions, Technovation. 32 (2012) 419–429.
[48] J. Callahan, E. Lasry, The importance of customer input in the development of very new products, RD Manag. 34 (2004) 107–120.
[49] C. Fuchs, M. Schreier, Customer Empowerment in New Product Development, J. Prod. Innov. Manag. 28 (2011) 17–32.
[50] M.A. Kaulio, Customer, consumer and user involvement in product development: A framework and a review of selected methods, Total Qual. Manag. 9 (1998) 141–149.

[51] E.J. Nijssen, B. Hillebrand, J.P.J. de Jong, R.G.M. Kemp, Strategic Value Assessment and Explorative Learning Opportunities with Customers, J. Prod. Innov. Manag. 29 (2012) 91–102.
[52] G. Sánchez-González, N. González-Álvarez, M. Nieto, Sticky information and heterogeneous needs as determining factors of R&D cooperation with customers, Res. Policy. 38 (2009) 1590–1603.
[53] M. Bogers, A. Afuah, B. Bastian, Users as Innovators: A Review, Critique, and Future Research Directions, J. Manag. 36 (2010) 857–875.
[54] P.D. Morrison, J.H. Roberts, E. von Hippel, Determinants of User Innovation and Innovation Sharing in a Local Market, Manag. Sci. 46 (2000) 1513–1527.
[55] C. Baldwin, E. von Hippel, Modeling a paradigm shift: From producer innovation to user and open collaborative innovation, Organ. Sci. 22 (2011) 1399–1417.
[56] C. Lüthje, C. Herstatt, The Lead User method: an outline of empirical findings and issues for future research, RD Manag. 34 (2004) 553–568.
[57] P.D. Morrison, J.H. Roberts, D.F. Midgley, The nature of lead users and measurement of leading edge status, Res. Policy. 33 (2004) 351–362.
[58] M. Ozer, The roles of product lead-users and product experts in new product evaluation, Res. Policy. 38 (2009) 1340–1349.
[59] J. Füller, K. Matzler, M. Hoppe, Brand Community Members as a Source of Innovation, J. Prod. Innov. Manag. 25 (2008) 608–619.
[60] D. Harrison, A. Waluszewski, The development of a user network as a way to re-launch an unwanted product, Res. Policy. 37 (2008) 115–130.
[61] S. Nambisan, Designing Virtual Customer Environments for New Product Development: Toward a Theory, Acad. Manage. Rev. 27 (2002) 392–413.
[62] S. Nambisan, R.A. Baron, Different Roles, Different Strokes: Organizing Virtual Customer Environments to Promote Two Types of Customer Contributions, Organ. Sci. 21 (2009) 554–572.
[63] E. von Hippel, "Sticky Information" and the Locus of Problem Solving: Implications for Innovation, Manag. Sci. 40 (1994) 429–439.
[64] C. Lüthje, C. Herstatt, E. von Hippel, User-innovators and "local" information: The case of mountain biking, Res. Policy. 34 (2005) 951–965.
[65] S. Ogawa, Does sticky information affect the locus of innovation? Evidence from the Japanese convenience-store industry, Res. Policy. 26 (1998) 777–790.
[66] R. Roy, M. Sarkar, Knowledge, firm boundaries, and innovation: Mitigating the incumbent's curse during radical technological change, Strateg. Manag. J. (2015).
[67] A.K. Chatterji, K. Fabrizio, How Do Product Users Influence Corporate Invention?, Organ. Sci. 23 (2011) 971–987.
[68] T.G. Schweisfurth, C. Herstatt, How internal users contribute to corporate product innovation: the case of embedded users, RD Manag. (2014).
[69] S. Hyysalo, S. Usenyuk, The user dominated technology era: Dynamics of dispersed peer-innovation, Res. Policy. 44 (2015) 560–576.
[70] P. Oliveira, E. von Hippel, Users as service innovators: The case of banking services, Res. Policy. 40 (2011) 806–818.
[71] M.P. Bhave, A process model of entrepreneurial venture creation, J. Bus. Ventur. 9 (1994) 223–242.

[72] S. Haefliger, P. Jäger, G. von Krogh, Under the radar: Industry entry by user entrepreneurs, Res. Policy. 39 (2010) 1198–1213.
[73] S.K. Shah, M. Tripsas, The accidental entrepreneur: the emergent and collective process of user entrepreneurship, Strateg. Entrep. J. 1 (2007) 123–140.
[74] S.W. Smith, S.K. Shah, Do Innovative Users Generate More Useful Insights? An Analysis of Corporate Venture Capital Investments in the Medical Device industry, Strateg. Entrep. J. 7 (2013) 151–167.
[75] C.M. Christensen, J.L. Bower, Customer Power, Strategic Investment, and the Failure of Leading Firms, Strateg. Manag. J. 17 (1996) 197–218.
[76] R.K. Chandy, G.J. Tellis, Organizing for Radical Product Innovation: The Overlooked Role of Willingness to Cannibalize, J. Mark. Res. 35 (1998) 474–487.
[77] C.M. McDermott, G.C. O'Connor, Managing radical innovation: an overview of emergent strategy issues, J. Prod. Innov. Manag. 19 (2002) 424–438.
[78] J.M. Bonner, O.C. Walker, Selecting Influential Business-to-Business Customers in New Product Development: Relational Embeddedness and Knowledge Heterogeneity Considerations, J. Prod. Innov. Manag. 21 (2004) 155–169.
[79] R.M. Grant, Towards a Knowledge-Based Theory of the Firm, Strateg. Manag. J. 14 (1996) 109–122.
[80] R.M. Grant, Prospering in Dynamically-competitive Environments: Organizational Capability as Knowledge Integration, Organ. Sci. 7 (1996) 375–387.
[81] B. Kogut, U. Zander, Knowledge of the Firm, Combinative Capabilities, and the Replication of Technology, Organ. Sci. 3 (1992) 383–397.
[82] S. Hansen, N. Berente, K. Lyytinen, Requirements in the 21st Century: Current Practice and Emerging Trends, in: K. Lyytinen, P. Loucopoulos, J. Mylopoulos, B. Robinson (Eds.), Des. Requir. Eng. Ten-Year Perspect., Springer Berlin Heidelberg, 2009: pp. 44–87.
[83] S.T. Cavusgil, R.J. Calantone, Y. Zhao, Tacit knowledge transfer and firm innovation capability, J. Bus. Ind. Mark. 18 (2003) 6–21.
[84] H. Scarbrough, Knowledge management, HRM and the innovation process, Int. J. Manpow. 24 (2003) 501–516.
[85] L.B. Cardinal, T.M. Alessandri, S.F. Turner, Knowledge codifiability, resources, and science-based innovation, J. Knowl. Manag. 5 (2001) 195–204.
[86] I. Nonaka, A Dynamic Theory of Organizational Knowledge Creation, Organ. Sci. 5 (1994) 14–37.
[87] M. Polanyi, The Tacit Dimension, London, Routledge & K. Paul, 1967.
[88] A.C. Inkpen, A. Dinur, Knowledge Management Processes and International Joint Ventures, Organ. Sci. 9 (1998) 454–468.
[89] E.A. Smith, The role of tacit and explicit knowledge in the workplace, J. Knowl. Manag. 5 (2001) 311–321.
[90] R.K. Yin, Case Study Research: Design and Methods, Sage Publications, 2009.
[91] K.M. Eisenhardt, M.E. Graebner, Theory Building From Cases: Opportunities And Challenges, Acad. Manage. J. 50 (2007) 25–32.
[92] K.M. Eisenhardt, Building Theories from Case Study Research, Acad. Manage. Rev. 14 (1989) 532–550.

[93] L.M.D. Luca, K. Atuahene-Gima, Market Knowledge Dimensions and Cross-Functional Collaboration: Examining the Different Routes to Product Innovation Performance, J. Mark. 71 (2007) 95–112.
[94] C. Ashurst, A. Freer, J. Ekdahl, C. Gibbons, Exploring IT-enabled innovation: A new paradigm?, Int. J. Inf. Manag. 32 (2012) 326–336.
[95] M.Q. Patton, Qualitative Research & Evaluation Methods: Integrating Theory and Practice, SAGE Publications, 2014.
[96] M. Lewis-Beck, A. Bryman, T. Liao, Encyclopedia of Social Science Research Methods, SAGE Publications, Inc., 2455 Teller Road, Thousand Oaks California 91320 United States, 2004.
[97] M. Hennink, I. Hutter, A. Bailey, Qualitative Research Methods, SAGE, 2010.
[98] G. Burtch, Y. Yoo, A. Weiss, Digital Innovation and Craftsmanship: the Case of C. F. Martin & Company, in: ICIS 2010 Proc., 2010.
[99] A.L. Strauss, Qualitative Analysis for Social Scientists, Cambridge University Press, New York, 1987.
[100] M. Alavi, D.E. Leidner, Review: Knowledge Management and Knowledge Management Systems: Conceptual Foundations and Research Issues, MIS Q. 25 (2001) 107–136.
[101] K.J. Boudreau, Let a Thousand Flowers Bloom? An Early Look at Large Numbers of Software App Developers and Patterns of Innovation, Organ. Sci. 23 (2011) 1409–1427.
[102] N. Berente, S. Hansen, K. Lyytinen, High Impact Design Requirements - Key Design Challenges for the Next Decade, in: K. Lyytinen, P. Loucopoulos, J. Mylopoulos, B. Robinson (Eds.), Des. Requir. Eng. Ten-Year Perspect., Springer Berlin Heidelberg, 2009: pp. 1–10.
[103] E. Danneels, Tight–loose coupling with customers: the enactment of customer orientation, Strateg. Manag. J. 24 (2003) 559–576.
[104] S.F. Slater, J.C. Narver, Customer-Led and Market-Oriented: Let's Not Confuse the Two, Strateg. Manag. J. 19 (1998) 1001–1006.