From Process to Practice: Towards a Practice-based Model of Digital Innovation

Completed Research Paper

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Abstract

The ongoing digitalization of many corporate functions, including the innovation process, brings about fundamental changes that urge us to rethink established theories. Facilitating digital innovation requires a deep understanding of the actual practices that are carried out by innovating people with the help of artifacts. In this paper, we study the use of artifacts and illustrate their different roles in the underlying innovation practices to provide rich insights into digital innovation from a practice perspective. Grounded in a nearly three year-long, qualitative case study at two Swiss software companies and an extensive set of empirical data, this paper conceptualizes four interrelated digital innovation practices, namely making sense of an idea, aligning mental models, negotiating solution paths, and crafting an idea. We suggest a practice-based model of digital innovation, specify a set of practices for enabling digital innovation in organizations, and clarify the role of artifacts in digital innovation practices.

Keywords: Digital Innovation, Practice Theory, Boundary Object, Epistemic Object, Activity Object, Material Infrastructure, IS development, Interpretive field study, Sensemaking, Artifacts

Introduction

Facilitating digital innovation, i.e. the creation of new products and services that result from the use of information technology (IT) or result in new IT, has become an essential practice for companies to compete and lead in today's digitized world (Fichman et al., 2014; Nambisan et al., 2017; Yoo et al., 2010, 2012). However, while classic innovation studies have mostly regarded the innovation process as a well-defined set of clearly demarcated phases, malleable information technologies seem to break down the boundaries between innovation process phases and bring about greater overlap in their temporal and spatial evolution (Nambisan et al., 2017; Yoo et al., 2010). As a result, many companies struggle to support employees actively and collectively when they create digital innovations (Desouza, 2011; Hargadon and Bechky, 2006; Høyrup et al., 2012). There has been a number of calls to better understand the fundamental changes imposed by new IT and the therewith associated changing nature of work (Nambisan et al., 2017, Riemer and Johnston, 2017, Yoo et al., 2012, 2010).

In related disciplines, a practice perspective has proven to be suitable for looking at the bottom-up emerging, multifaceted, and serendipitous nature of work (e.g. Majchrzak et al., 2012; Nicolini, 2011; Orlikowski, 2002). For the context of digital innovation, a practice perspective can help to see innovation not only as a one-off moment without a history or future, but rather as a continuous, ongoing, and collective accomplishment of something people do and enact (Pantzar and Shove, 2010). Accordingly, as a 'digital innovator', a person carries out the practice of digital innovating. Any innovation process, whether digital or not, can only unfold as a sequence of practices. The appropriate level of analysis to capture the complexity of digital innovation is, therefore, at the level of practice (cf. Tuomi, 2002, p. 19).

A fundamental starting point to understand practices is to study the use of artifacts (Carlile et al., 2013). In order to address the above-mentioned changes related to the use and creation of new IT artifacts, we suggest studying the artifacts that innovators use to form, evolve, and add to a shared innovation agenda within organizations. As some artifacts break up spatial and temporal innovation process boundaries, understanding their mediating role becomes ever more important (Nambisan et al. 2017). Thus, as a first step, we ask:

1) *What role do artifacts play in digital innovation practices?*

Leveraging a theoretical framework, recently developed by Nicolini et al. (2012) for studying artifact usage in collaborative practices, we analyze the artifact-mediated practices of innovating people. This perspective will then allow us to further unfold the existing digital innovation practices and to answer a second question:

2) Through which practices do people enact digital innovation in organizations?

Empirically grounded in an in-depth case study at two Swiss software companies, we develop a practice-based model of digital innovation. Over a period of nearly three years, we studied and engaged with their practices related to the development of digital innovations. We observed that people enact digital innovation through alternating sequences of individual and interpersonal artifact-mediated practices.

Our contribution is twofold: Firstly, we apply Nicolini et al.'s (2012) framework in order to illustrate how artifacts play different role in innovation practices. As outcome, we present four digital innovation practices, namely *making sense of an idea, aligning mental models, negotiating solution paths* and *crafting an idea*, and synthesize them into a practice-based model of digital innovation. The model explains how people collectively innovate with and toward artifacts. The model reflects the shift from centralized focal innovation agents to decentralized innovation collectives and contributes to theorizing about facilitating innovations in the digital age (as called for by e.g. Nambisan et al., 2017). Our study implies that artifact-mediated innovation practices should be a central element of digital innovation research and practice. Secondly, by applying Nicolini et al.'s framework in the context of digital innovation, we are not only able to specify practices and the use of artefacts therein, but also to critically reflect on the framework and its application. Moreover, we are able to show that the appropriateness of the use of some artifacts depends on the underlying practice. Thus, we inform future studies on the design and use of information systems that support these practices.

The remainder of this paper is structured as follows. Section 2 embraces the theoretical foundations by summarizing related literature on managing digital innovation, and introducing the framework that guided our analysis of artifacts in digital innovation practices. In Section 3, we provide information about our

interpretive field study (Walsham, 2006, 1995) at two Swiss software companies, and our use of qualitative methods for data analysis and theory building. In Section 4 we present the results that emerged from our study in form of four digital innovation practices. Section 5 synthesizes our findings and, based thereupon, presents the practice-based model of digital innovation, followed by a discussion of its implications for research and practice. Finally, section 6 sums up the key takeaways of the study.

Related Work

A Practice Perspective on Digital Innovation

The distinctive nature of digital innovation manifests itself very clearly in the innovation practices of the software industry. However, understanding and supporting innovation practices in industrial software development processes remains an unsolved problem.

The software and related services segment has been the economic powerhouse of the IT industry for the last five decades, with annual growth rates and real contributions to GDP steadily outperforming most other industry segments in economies around the globe (BSA, 2009; Gartner, 2016; MacCormack, 2001; Zmud, 1983). In most of today's products and services, software is a key differentiating component as well as an innovation enabler (Svensson and Taghavianfar, 2015; Yoo et al., 2012). Likewise, developing innovative software products and services is an uncertain, risky, and failure-prone challenge, but essential for software firms to thrive and survive (Nambisan et al. 2017).

For many years, companies have sought to innovate by opening up towards networks of internal and external collaborators (Chesbrough, 2003) and helping employees to realize ideas within the boundaries of their organization (Desouza, 2011). Against this backdrop, various academic disciplines have engaged intensively with this steady challenge of supporting creativity and innovativeness in industrial software development. Recently, scholars have suggested to put stronger focus on seizing the nearly limitless opportunities to innovate facilitated by digital artifacts (Yoo et al., 2012, 2010). First studies indicate that we are only at the beginning of imagining the potential of digital artifacts (Fichman et al., 2014; Nambisan et al., 2017; Yoo et al., 2012) and that it is time to elaborate a body of literature on digital innovation that embraces and refines established innovation management concepts (Yoo, 2013).

This is visible on the example of theorizing the innovation process. The prevailing view in the existing innovation literature is a discrete, linear, and sequential innovation process with clearly ordered, differentiated, and consecutive phases. For instance, Tidd and Bessant (2011) divide the innovation process into *search, select, implement*, and *capture*. Chesbrough (2003) differentiates between *research* and *development*. Desouza's (2011) innovation process consists of *idea generation, advocacy & screening, experimentation, commercialization,* and *diffusion & implementation*. And Fichman et al. (2014) distinguish between *discovery, development, diffusion,* and *impact*.

Whereas we do not want to question the necessity of these activities, it is important to note that the purpose of creating such innovation process models by sequentially combining them is essentially to keep an overview over the activities of individual agents and to organize their activities reasonably well according to the given, recurring circumstances (Tidd and Bessant, 2011). As such, these models are necessarily and by definition a simplified approximation to an innovation process that unfolds sequentially in time from the perspective of a focal innovation agent. However, with the ongoing digitization of nearly all business functions - including the innovation process - agency shifts from a pre-defined, centralized set of focal innovation agents, who steer and organize innovation processes, to decentralized innovation collectives with diverse goals, motives and capabilities (Nambisan et al., 2017). Associated therewith, scholars have questioned whether received innovation process models appropriately capture the reality in a digital setting (e.g. Nambisan et al., 2017, 2014; Swanson and Ramiller, 2004; Yoo, 2013).

It is in line with those calls for action that we direct our attention to studying the actual practices of innovative people who actively and collectively create digital innovations. The above-mentioned set of activities that aim at creating new products and services with IT and toward new IT shall be our working definition of digital innovation for this study.

The Role of Artifacts in Innovation Practices

When defining practices as "embodied, materially mediated arrays of human activity centrally organized around shared practical understandings", Schatzki (2001, p. 2) directs special attention to the mediating 'material', i.e. the role of artifacts in practice. In line with this view, practice-based studies in the IS field have gone hand in hand with a parallel emphasis on the social and material nature of practices, where the relationship between human activity and technology is one of mutual mediation (Leonardi, 2011; Orlikowski and Barley, 2001). As Orlikowski (2007) puts it, a practice perspective unveils that "materiality is integral to organizing, positing that the social and the material are *constitutively entangled* in everyday life" (p. 1437, italics in original).

The term *artifact*, when used in this paper, refers to any kind of material object that innovators create and/or use in practice. An artifact, in our understanding, is always practice-oriented. It can be a means or an end, but the underlying practice determines its role (Kaptelinin and Nardi, 2009). As some artifacts contribute to the breakup of spatial and temporal boundaries between innovation process phases (Nambisan et al. 2017), understanding their role becomes ever more important. Moreover, analyzing artifact usage yields an opportunity to better understand the underlying practices (Riemer and Johnston, 2014). In innovation practices, artifacts can manifest an abstract idea conceptualization and are thus often emergent, unfinished, and partial. They may represent an envisaged solution, embody multiple viewpoints, and enable a shared understanding (Star and Griesemer, 1989). An artifact can mediate both individual work and collaboration (Nicolini et al., 2012). It can be used in a private space, confronting the innovator with a first prospect of a new idea, thereby advancing the chain-of-thoughts and inspiring further development (Rheinberger, 1997). In addition, an artifact can be used to collect feedback and build a social coalition for a further development of the innovation. As such, the artifact can be an important tool to facilitate communication and decision-making (Ciriello et al., 2014).

Artifacts affect many aspects of our work and private life, and practices can be seen as outcome of the relationship between human and material aspects of technology use (Cecez-Kecmanovic et al., 2014). As a consequence, many academics direct considerable research attention to the role of artifacts in practices, and how they can support knowledge sharing, collaboration, and innovation. An artifact lens facilitates uncovering the "process of materialization enfolding in material-discursive practices of IS development, implementation, and use" (Cecez-Kecmanovic et al., 2014, p. 812). For instance, a carpenter who is hammering encounters a hammer as something for doing what carpenters do, namely hammering nails, and for being what carpenters are, namely craftsmen; the hammer draws its role from the carpentry practice, and draws its purpose from the practice it is used for and constitutive of, namely hammering (Riemer and Johnston, 2014). Accordingly, as digital technology exists only as technology-in-use embedded in a specific practice, the researcher may obtain a better understanding of the underlying practices through studying artifacts in use. Not unlike archaeologists, who study ancient cultures through analyzing left material traces, practice theorists seek to understand contemporary sociality through the ecology of artifacts that surrounds and shapes our everyday life (Knorr-Cetina, 1997).

Artifact Lenses to Study Practices

The literature describes various lenses that make apparent the important role of artifacts in the context of various practices. Nicolini, Mengis, and Swan (2012) compiled some of the most important ones into one perspective. This framework embraces four lenses that we discuss in the following: *boundary objects, epistemic objects, activity objects, and material infrastructure*.

The *boundary object* lens sees artifacts as translational and transformational devices at functional, professional, or organizational boundaries (Carlile, 2002). Artifacts become boundary objects when they are flexible yet robust enough to develop and maintain coherence across intersecting social worlds, satisfying the information requirements of each (Star and Griesemer, 1989). They are flexible because their structure has to be sufficiently loose to allow for interpretive flexibility among collaborating social groups (Bartel and Garud, 2003). But they are also robust because they provide a form of reification around which practices, cooperative work, and emergent, shared meanings can be coordinated (Lave and Wenger, 1998). Boundary objects range from visible artifacts such as PowerPoint slides (Ciriello et al., 2015), project repositories (Nicolini et al., 2012), standardized forms, sketches, drawings (Carlile, 2002), and software prototypes (Ciriello et al., 2017; Doolin and McLeod, 2012), to more abstract objects such as metaphors

(Koskinen, 2005), up to discussions and research projects (Kimble et al., 2010). The boundary object lens may help to shed more light on *how* artifacts play an active role in various practices (Levina and Vaast, 2005). Taken alone, however, boundary objects do not help us understand *why* people make the effort for alignment, and we know yet little about their potential for creativity and innovativeness (Eppler et al., 2011). Nicolini et al. (2012) argue that there are complementary concepts, as we summarize in the following.

The *epistemic object* lens foregrounds not only the how, but also the why of objects in practices. Originally introduced by science historian Hans-Jörg Rheinberger (1997), the epistemic object lens describes a kind of artifact that is "always in the process of being materially defined" (Knorr-Cetina, 2001, p. 181). Epistemic objects are question-generating and act as a source of interest and motivation for further research and development "by virtue of their preliminarity, of what we do not yet know about them" (Rheinberger, 2005, p. 407). Their lack of completeness creates emotional attachment and the desire to fill a void (Knorr-Cetina, 1999). As object of desire, epistemic objects keep together individuals in groups, making them feel and work like a community because of "what they [are] after and not simply because of who they are" (Nicolini et al., 2012, p. 620). For this reason, epistemic objects can be regarded as a central source of organizational innovation and change (Miettinen and Virkkunen, 2005). Being absorbed into the practice of pursuing an epistemic object is a key reason why curious people are willing to work long hours. Classic examples are the objects of investigation in strategizing efforts, scientific research projects, or innovation processes. An important characteristic of epistemic objects is their capacity to unfold indefinitely, meaning that they can never be fully attained (Knorr-Cetina, 1997). Thus, partial objects mediate their investigation, in a sense that the investigators interact with the necessarily partial material representations of the epistemic object, such as models, blueprints, or sketches (Werle and Seidl, 2015).

With the *activity object* lens, Nicolini et al. (2012) offer a complementary concept that foregrounds the emergent, fragmented, and constantly expanding nature of artifacts in practice. Rooted in the cultural-historical activity theory of psychologists Lev Vygotsky and Alexei Leontiev, the activity object lens sees artifacts as "prospective outcomes that motivate and direct activities, around which activities are coordinated, and in which activities are crystallized (…) when the activities are complete" (Kaptelinin and Nardi, 2009, p. 6). This view foregrounds that all practices are essentially object-oriented and artifact-mediated. They are *object-oriented* in a sense that each practice both pursues and produces some kind of object (or objective), i.e. durable concerns and carriers of motives that generate foci of attention, effort, and meaning (Engeström, 1987). And they are *artifact-mediated* in a sense that interactions between the person and its object are mediated by cultural artifacts that are internalized by participating in common practices with other people (Miettinen and Virkkunen, 2005). Classic examples are software prototypes, shared to-do lists, or the different concerns of researchers in interdisciplinary research projects. In software development, activity objects like mock-up prototypes may serve as design representations containing multiple ideas that mediate between designers, products, and users. They are open to multiple interpretations from various groups and are as, such, not very successful boundary objects (Bødker 1996). The activity object lens offers the distinctive insight that artifacts can function "not only as instruments of translation (as per boundary objects) and sources of attraction (as per epistemic objects), but also as triggers of contradictions and negotiation" (Nicolini et al., 2012, p. 620). Activity objects are problem spaces into which people project different views and perceptions to negotiate a consensus.

While the above three lenses foreground the important role artifacts sometimes play in practices, Nicolini et al. (2012) add, for the sake of completeness, that artifacts not always live in the center of our attention. They often perform subtle background work and remain unconsciously transparent in everyday work. The *material infrastructure* lens foregrounds the work of these mundane objects, or the "'stuff' of everyday live" (Nicolini et al., 2012, p. 622). Material infrastructure can be seen as any web of objects that emerges "when local practices are afforded by a larger-scale technology, which can be used in a natural, ready-to-hand fashion" (Star and Ruhleder, 1996, p. 112). Classic examples are software work tools that are embedded in a larger web of object including other software, hardware (PC, mouse, keyboard, monitor, etc.), desk, chair, building, electricity, and so on. Taken alone, these artifacts may seem transparent or even insignificant, but without them constituting the fundamental material infrastructure of everyday work, practices would be difficult to enact.

Table 1. Artifact Lenses in Nicolini et al.'s (2012) Framework

Lens	Short Description
Boundary Object (Star and Griesemer, 1989)	Boundary objects enable collaboration by developing and maintaining coherence across social worlds.
Epistemic Object (Rheinberger, 1997)	Epistemic objects embody what one does not yet know and thereby generate desire and attachment through their unfulfilled nature.
Activity Object (Engeström, 1987)	Activity objects embody different types of knowledge, thereby generating contradictions, triggering collaboration, directing activities, and sparking innovation.
Material Infrastructure (Star and Ruhleder, 1996)	Material infrastructure comprises everyday mundane objects that support and shape collaboration in their conjunction by forming an ecology of supporting objects.

Table 1 gives a summarizing overview over the four artifact lenses in Nicolini et al.'s (2012) framework. In a nutshell, it facilitates a deep-going analysis of practices. We should bear in mind that artifacts are not necessarily bound to one of these four theoretical approaches, and neither do they follow a one-way trajectory. They are rather able to change their roles back and forth, depending on the social and material constellation in which they are embedded (Nicolini et al., 2012).

Research Method

We conducted an interpretive case study (Klein and Myers, 1999; Walsham, 2006, 1995) at two Swiss software companies in order to obtain an in-depth understanding of digital innovation practices from a participant's perspective. Over the course of nearly three years, from February 2013 until December 2015, we zoomed in and out iteratively on the practices at the companies (Nicolini, 2009). We entered the research site with little previous understanding of digital innovation practices, and the theoretical foundation evolved over time according to our deepening understanding (Walsham, 2006).

Research Relationship and Case Selection

The above-summarized related literature indicates that digital innovation practices can be observed in organizations with high activity of employee-driven innovation (Desouza 2011), high degree of internal and external collaboration (Chesbrough 2003), and high involvement of digital artifacts in the development and outcome of the innovation (Yoo et al. 2010). Hence, we turned to the following two companies that focus on creating conditions where employees realize ideas. We began with an in-depth case study in one location and then expanded to another location by following emerging relations (Walsham, 2006). In both companies, work is focused on creating novel, IT-based solutions to novel problems, for which they heavily rely on an extensive network of customers, partners, and research institutions. The style of involvement with BITS was that of an embedded researcher having in-depth access to data, infrastructure, and people, who viewed the researcher as one of 'them' (Walsham 2006). The style of involvement with CustomSoft was that of an outside observer who was not seen as having a direct personal stake in various interpretations at outcomes, with personnel being relatively frank in expressing their views (Walsham 2006). Through these complementary approaches, we had the unique opportunity to study practices in different innovation projects.

Case Company 1: Banking and IT Solutions (BITS). Through the development, distribution, and operation of its proprietary core banking system, BITS rapidly grew to a market leader for banking software. The

global financial crisis after 2008 increased the pressure to innovate and diversify the company's market offerings. In 2012, the executive board initiated a research collaboration with our university institution on improving the innovative capacity of the around 1400 employees worldwide. At that time, independently thereof, the first author of this study was employed at BITS, where he actively participated in the development of a new software product, and obtained an important practical understanding of the underlying work practices. The author joined our emerging research collaboration with a PhD project while staying involved at BITS as embedded researcher to cooperate with employees and maintain constant access to data, infrastructure, and people.

Case Company 2: Custom Software Engineering (CustomSoft). As an engineering company founded by a group of PhD students, the core business of CustomSoft is the development of software applications on client order. Customer segments include transport, health, and space agencies, as well as public administration, banks, and insurances. In addition to software development, the around 350 employees offer complementary services, such as technical consulting, project management, and requirements engineering. In an effort to better leverage their employee's creative potential, the management board initiated a research collaboration with us. This comparative study with CustomSoft helped us to validate, extend, and refine the findings of the BITS study.

Data Collection

We used an iterative approach to data collection and analysis, moving back and forth between theories and the different interpretations of the case study material until a coherent picture emerged (Klein and Myers, 1999). Our data collection followed the principle of triangulation (Silverman, 2006, p. 291). We examined the research issue from different sides, compiling multiple interpretations obtained from interviews, observations, field notes, and documentary material into a rich dataset (Klein and Myers, 1999). Based on the principle of theoretical sampling, we selected, collected, and analyzed new data slices according to what was necessary for the emerging theory (Glaser, 1978). The first author was the primary responsible for collecting all data and interviewed 95 experts involved in the five innovation projects. By interviewing such a wide range of participants with differing roles and positions, we were able to document multiple interpretations of the practices under study (Klein and Myers, 1999, p. 77).

We used a semi-structured interview guideline to ensure topical focus and consistency while also allowing participants to freely express their views (Walsham, 2006). We asked participants to precisely describe concrete situations where they used artifacts to create or communicate innovative ideas, along with an assessment of the situation. This included describing the purpose of the artifact; how well the artifact served its intended purpose; form factors along with design rationales; and user groups. During these interviews, the participants typically described concrete practices around concrete artifacts, of which we collected in total 480 from participants or intranet platforms. In addition, the author spent in total 1538.5 hours at the companies to conduct participant observations. Field reports and, where possible, photographs complemented the observations.

Data Analysis and Interpretation

Our data analysis and interpretation followed the principle of the hermeneutic circle, which suggests that "we come to understand a complex whole from preconceptions about the meanings of its parts and their interrelationships" (Klein and Myers, 1999, p. 71). Using grounded theory methods, we inductively generated shared meaning from the collected data through qualitative data analyses practice (Walsham, 1995). In multiple iterations, we moved back and forth between data and theories, interrogating field material to check whether the data supported emerging claims and, conversely, switching between theoretical lenses to make sense of the empirics (Walsham 2006). We recorded and transcribed all but two interviews to capture a full description and facilitate later in-depth analysis (Walsham, 1995).

We then cross-checked the transcriptions among the research team and analyzed them in MAXQDA using open, axial, and selective coding techniques (Corbin and Strauss, 1990). We started with open coding, i.e. coding the entire data set to generate many tentative categories and their possible properties and relationships (Corbin and Strauss, 1990). In this case, we identified over 200 tentative categories (e.g. materiality, personal characteristics, process phase, practices, purposes). We proceeded with axial coding, i.e. making connections between sub-categories to construct a more comprehensive scheme (Corbin and

Strauss, 1990). Here, we identified key terms that constitute the conceptual model (e.g. sensemaking, alignment, negotiation, crafting). We concluded with selective coding, i.e. unifying categories and relating them to a core category (Corbin and Strauss, 1990). In our case, based on constant comparison between our emergent conceptual model and existing theory, we developed the practice-based model of digital innovation.

Results: Digital Innovation Practices at BITS and CustomSoft

This section conceptualizes the set of digital innovation practices that emerged from our case study, namely: 1) *making sense of an idea*, 2) *aligning mental models*, 3) *negotiating solution paths*, and 4) *crafting an idea*. We begin each section by framing the practice, followed by an empirically grounded description of the practice. We conclude each practice with an interpretation through the framework provided by Nicolini et al. (2012), serving us to assign meaning to the observations.

Figures 1-3 (from left to right): 1) Software Engineer scribbling together a paper prototype. 2) Two Software Architects reasoning around printouts of architectural diagrams. 3) Whiteboard sketch from a spontaneous discussion

Practice 1: Making Sense of an Idea

A typical challenge early in any innovation endeavor is developing an understanding of the idea and its potential impacts. Here, artifacts help innovators anticipate how the idea will potentially impact the future, thereby advancing the chain-of-thought and inspiring further development. When a creative spark generates the need to create and reflect upon a tangible prospect of an idea, people turn to easy-to-use, ready-to-hand drawing tools such as mind mapping tools, PowerPoint, or just simple notepads. For instance, many participants create early sketches in PowerPoint:

> *"Every now and then, I open PowerPoint and simply draw for myself. I illustrate my creative process in there, and when I get the impression that something interesting comes out, I present it directly and discuss it further. That can for example be an architectural model or a process model when I want to improve a process, it can also be a mockup when it's about usability."* [i16, Product Manager, BITS]

This participant describes the importance of thinking an idea through for oneself before communicating it to others, and of being able to easily communicate the idea to others without many intermediate steps. In this case, PowerPoint was appropriate to sketch and communicate the idea with a tool that is widespread and universally understood. We also observed that people use free-form tools such as whiteboards, smartboards, flipcharts or notepads extensively when making sense of an idea, as exemplified here:

> *"I usually take a notepad and draw for myself [to anticipate] how the UI could look like. Thereby I obtain a first impression of the usability, because [...] I have to think about how it will look in the end while I'm already drawing. Thereby I get to ideas, sketches, and concepts, through which I see directly when something does not make sense. Then I can throw the paper into the bin and start over. When I do it already like this, I obtain a relatively good image of how it will later look like in reality. "* [i11, Technical Lead, BITS; cf. figure 1]

This participant describes how sketching ideas with paper and pencil helps with reflecting on the positive and negative aspects of an idea and its particularities. Contrary to a computer screen with all its sources of distraction, paper and pencil help to stay focused on the important aspects of an idea, and force the creator to think an idea through before implementing it, thereby preventing unnecessary later correction effort.

Other participants prefer digital drawing tools over physical ones to support their sensemaking. For instance, an interaction designer at CustomSoft, who created visual concepts for the in-train cockpit view innovation project, uses Axure to draw user interfaces, and reflects on this digital artifact as follows:

> *"The question is: what do you use these things for? And for me, the actual issue is: You as a designer realize what you want. You also do it when nobody else around you wants to see it. Firstly, you have to generate and discard ideas. That's the digital scrapbook; where Leonardo [Da Vinci] used to scribble his wings into, you do it electronically now - to find ways, to discard ways, to see how it feels."* [i82, Interaction Designer, CustomSoft]

In sum, *making sense of an idea* has the goal to develop a clear understanding of an idea. Here, people use artifacts to generate, refine, and reflect upon a tangible prospect of the idea. Artifacts help to anticipate what possible design paths could be relevant and what envisaged design options could be acceptable or unacceptable. As innovators consider, construct, or interact with the artifact, it helps them to organize thoughts and to understand what they really want to achieve. It can also be an important precursor for communicating an idea to others and, thereby, supports further practices.

Interpretation: Epistemic Objects in Digital Innovation Practices

Our inquiry of artifact use in innovation practices begins at the point where a creative spark leaps across the minds of innovators, and they set nascent ideas in motion. From studying BITS and CustomSoft, we learned that innovators often make sense of ideas with lightweight instruments that help them generate and refine ideas. Making sense of an idea is a fundamental practice for understanding and designing interactions between the envisaged product and its potential users. Be it a PowerPoint drawing or a paper prototype, innovators make sense of ideas as they construct, regard, and reason around artifacts to organize their thoughts. Interpreting these observations through the artifact lenses, we can describe *making sense of an idea* as the practice of using artifacts to pursue an *epistemic object*.

Low-maturity artifacts such as design sketches give the creator an impression of the potentials and constraints that emerge when the idea meets the realm of reality. As people create tangible prospects of their idea, they fuel an ongoing feedback process of materially defining an epistemic object that embodies what does not yet exist in the world. Epistemic objects, often partially represented as paper prototypes or sketchy screens, awake and maintain the desire to fulfill an idea. Working towards something that does not exist yet is often a crucial source of motivation. What drives people to realize ideas and invest a substantial amount of time and effort is not only the promise of a generous compensation or long-desired promotion, but also the desire for fulfillment triggered by the epistemic nature of the object. The epistemic object, for instance the possibility of an innovative product, triggers desire and attachment any time an individual comes closer to capturing it (cf. Nicolini et al. 2012). Such epistemic objects often do not motivate only one single individual, but also groups of innovators. Hence, epistemic objects may also trigger collaboration and keep together collections of creatives who alone could not make sense of the idea. But this only becomes possible when artifacts instantiate parts of the epistemic object.

Practice 2: Aligning Mental Models

From studying BITS and CustomSoft, we observed that the highly collaborative and network-based nature of digital innovation requires groups of innovators to speak the same language. The practice of *aligning mental models* has the goal to bring stakeholders with different views into alignment and converge on a shared understanding. When aligning mental models, innovators use artifacts to coordinate work, adjust interests, exchange ideas, collect feedback, establish a common language, bridge communication, and anchor discussions. Whiteboard discussions are a typical setting at BITS and CustomSoft in which innovators meet to brainstorm, develop new ideas, explore new topics, breakdown large topic blocks, and exchange specialized knowledge. One participant regards this as *"the simplest and most efficient way to build consensus and develop a shared understanding"* [i6, Technical Lead, BITS]. Especially in technical workshops, we observed that the whiteboard is an important tool to align mental models:

> *[The Standard Banking Suite (SBS) project team set the agenda for the meeting as increasing service orientation in the core product in order to elaborate the basis for the standard banking suite, which is currently the focus innovation project. The mission of the Web Self-Service (WSS) team is to support the implementation process and ensure compliance with the architectural patterns and technological consistency. Since weeks, however, the SBS project manager is dissatisfied with WSS' solution proposal.*

In his view, the proposal is too vague and does not fully reflect SBS' needs. The beamer displays a wiki page with the proposed software design from the WSS team]

SBS Project Manager: "I simply need to know how much effort it will take to build this. How many components do we have to touch, and is the concept feasible at all?"

WSS Project Manager: "We don't build dirty hacks here. The code must be maintainable. [Takes the mouse cursor to highlight a database schema on the wiki page projected on the wall] That would be our concept of this. That's a clean concept. I think you all agree that a replace mechanism would be a dirty concept, don't you?" [...]

WSS Project Manager: "But that concept will be clean in two months." [Vivid discussion]

WSS Software Architect: [stands up, walks to the whiteboard, draws two containers labeled C1 and C2] "The question is really simple: what will be part of component 1, and what will be part of component 2?"

SBS Software Architect: [stands up, joins his colleague, draws a deployment diagram around C1 and C2]: "When I said we do not want a replace mechanism I meant that we do not want it here in this part [points to the drawing]. My question was where you want to build this. As long as you keep that in C1 it's okay." [Both agree]

SBS Project Manager: "Can you please add that drawing to the wiki page, because when we read your solution proposal without that picture we did not understand it." [From field notes]

This whiteboard discussion shows how a tensed conflict between two parties can be resolved by co-creating an artifact to align mental models. The wiki page with the textual and tabular specifications failed to transfer knowledge from one team to the other. Although the wiki page was projected on the wall and visible for everyone, only the head of project team 1 sitting on the PC could contribute to it. It was only when the two software architects turned to the whiteboard to discuss the component modifications synchronously that they were able to resolve the conflict, establish a shared language and thereby maintain a shared understanding of the problem at hand. Photographs of such drawings are then often put on intranet wikis or hung up in the offices and innovators frequently use them to anchor discussions (cf. figure 2).

Often times, aligning mental models requires a combination of artifacts. For instance, in an early stage of the mobile banking suite project, the project team created software diagrams using standardized modeling notations such as UML or BPMN to create a shared understanding. For such diagrams to be effective, however, all collaborators need to understand the notation. When the project team discussed the software specification with the customer, the feedback was not as expected: *"In general, actually, feedback only comes when they see it graphically in front of them. Most of our customers cannot imagine what it means when they just read text. A (software) specification does not help much there." [i1, Software Architect, BITS].* The project team therefore proceeded to discuss the early ideas with a group of interaction design specialists.

From the software specification, the more technically versed designers created a set of wireframes, i.e. rough schematic representations of UI screens that assimilate line drawings, and used these to perform a walkthrough of a typical financial advisory encounter with a customer. This team learned that wireframes were a more effective instrument to discuss the raw ideas and get an overall impression whether the proposed system could be helpful in practice. In a subsequent step, the team created a software prototype to facilitate more fruitful discussions with the customer: *"This was insofar helpful as the customer could see 'ah, that's how it could look like.' The sole looking and touching helped to understand what we wanted to show." [i1, Software Architect, BITS].*

Interpretation: Boundary Objects in Digital Innovation Practices

Aligning mental models allows individuals as well as groups to readjust their understanding of the idea at hand. When it is crucial to bring different people into alignment, artifacts facilitate preserving an idea's integrity in different contexts through adhering to a shared language. These artifacts maintain coherence and create a shared understanding across technical, functional, and organizational boundaries. We observed how artifacts can help to collect feedback and bring a group into alignment. For instance, the above described whiteboard discussion triggered the creation of an artifact that facilitated coordinating future actions. Interpreting the practice of *aligning mental models* through the artifact lenses reveals that innovators use artifacts to construct boundary objects.

Examples for boundary objects from our case study include the UI screens, PowerPoint slides, handwritten sketches, and prototypes that innovators used to create a shared understanding among involved stakeholders. The structure of these boundary objects is sufficiently loose to allow for interpretive flexibility among various observers. Yet, these boundary objects incorporate a certain degree of robustness to provide a shared language through which different groups develop a shared understanding. As we learned from our case study, innovators at BITS and CustomSoft coordinate work by placing ideas, thoughts, and knowledge on boundary objects, here represented as whiteboard sketches, printed diagrams on the wall, or software prototypes. When the project teams at BITS and CustomSoft needed to exchange highly specialized and distributed knowledge, these boundary objects helped to bring groups into alignment, develop a shared understanding of a problem, and then pass crucial information from one locus to another. Through their tangibility, these boundary objects made collaboration possible among different groups and support innovators in organizing their collaborative discovery along the innovation trajectory.

Practice 3: Negotiating Solution Paths

The third practice, *negotiating solution paths*, has the goal to narrow down the possible solution space and agree on actions to take in order to approach a problem at hand. This includes illustrating and selecting solution options to reach a consensus on further actions. In this practice, groups of innovators typically project their different views, goals, and interpretations into the solution space. Here, artifacts function as means to unify these diverse and sometimes conflicting viewpoints into a shared object of discourse. From studying BITS and CustomSoft, we observed that innovators intentionally use artifacts to demonstrate an idea's desirability and feasibility. By showing instead of telling the envisaged benefits, artifacts help transgressing the many quality gates associated with digital innovation, be it to get skilled engineers to collaborate, to persuade managers of a funding decision, or to convince potential customers to adopt the envisaged innovation. For instance, one participant reported about an internal process innovation she initiated as part of the standard banking suite project in order to improve business process modeling and standardization. In that case, she managed to convince the responsible project team of accepting her idea using a MS Excel-based decision matrix, which illustrated the possible solution paths, each with pro and contra arguments. In a workshop, each project team member had to assign scores to the solution paths, resulting in a documented decision on further actions. She reflects on this experience:

> "*It all depends on the result I want to achieve: do I want a decision or only feedback? If I want a decision, I (am) quite careful about the preparation, because I have learned that I am only successful when I adequately illustrate what I want to achieve. (…) In my experience, the content can be really genuine, but if I present it badly and miss the first shot, the topic is over. Hence, when the topic is important to me, I prepare my artifacts very carefully, be it a PowerPoint, be it that decision matrix, or be it a (wiki) page*." [i8, Manager, BITS]

This participant points to the importance of using well-prepared illustrations when negotiating solution paths. If the artifact illustrates the important arguments in a clear way, and relevant stakeholders are able to bring in their opinion, it tends to be easier to find a consensus. Consider the following statement, where a project manager of the Web Self-Service project recalls a rather unsuccessful steering meeting: *"I recently learned that you already have to illustrate everything in an abstract on the first slide. Even in PowerPoint you need a management summary, because often times you don't even pass the first slide."* [i6, Technical Lead, BITS]. This participant acknowledges that a management summary with a concise problem statement and the main contribution in few sentences would have made it easier to find a consensus. At first, the project team was stuck for quite a while because the team could not solve some wicked problems with the relatively new model-driven software engineering frameworks that were used.

Customers and BITS management already began to fear that the product could eventually not be delivered. It was only when one software architect took the initiative to create a software prototype that showed, instead of told, what benefits the envisaged idea will deliver. *"I really had to put myself in front of the screen for two weeks to produce some code, more or less day and night. But eventually we had a (software) prototype that we could discuss."* [i31, Technical Lead, BITS]. The software prototype played an important role in persuading others and transgressing a quality gate. Particularly the more technically versed employees often struggle with finding the right arguments to persuade important decision makers of an idea. Managers at BITS and CustomSoft often point to the importance of challenging the employee. In their view, many "techies" lack the business know-how to formulate out the benefit of an idea. Many

discussions would be too technical and center on solutions that do not clearly address a problem. A common problem would be risk-aversion on the employees' side. Asking tough questions would be the best approach to test the idea's substance and the employee's commitment to it: "*The usual point of failure is when the employee has started, then is allocated again to another project and does not have time anymore, and hence the idea peters out after a few attempts. [They may even have created some] presentation and everyone asks 'whew, that was all?' At that point, everyone has lost interest and the employee lost motivation.*" [i24, Senior Manager, BITS]

This participant points to the importance of making ideas visible, along with who is responsible, in order to allow others to ask the crucial questions and ensure the employee is still motivated. For this purpose, both BITS and CustomSoft maintain designated idea wikis. The CustomSoft idea wiki is an open platform where all employees can submit, view, edit, and comment on ideas. There, employees can enter ideas using a fact sheet template with predefined sections. After an informal screening process of group discussion, the innovators are requested to submit more elaborate artifacts such as a five minutes' video presentation, a one-page poster, a rough business plan, a business model canvas, or a prototype. All employees are allowed to use a few working days to initiate an idea site, and blue-sky thinking ideas are explicitly encouraged. The start page features an activity stream, depicting the ideas to which members contribute frequently. In addition, the CustomSoft innovation board uses the idea wiki to track a project's status. This would also contribute to employee motivation and satisfaction: *"Our [idea wiki] is an important instrument. When someone posts an idea there, I always try to at least like or comment it. That's an encouragement aspect."* [i93, Senior Manager, CustomSoft].

In contrast to CustomSoft's open idea wiki, the BITS idea wiki is a rather closed platform where only administrators publish information about those selected ideas that have been presented at the idea fair, and ideas typically relate to a previously predefined area of the company's strategy. Here, an idea wiki page contains a 5-minute video presentation, the poster, additional information in text, and a comment function.

Interpretation: Activity Objects in Digital Innovation Practices

Negotiating solution paths allows people to iteratively narrow down the solution space. When it is crucial to agree on necessary further actions, artifacts facilitate targeted discussions by unifying the different views and interpretations of relevant stakeholders through their emergent, fragmented, and unfinished nature. It can be seen as an iterative communication and decision-making practice in which innovators search for a consensus on further actions. Here, we observed that an artifact can be used to ground judgments of the potential benefit and feasibility of a solution.

At both BITS and CustomSoft, innovators commonly used artifacts as a means to propagate an emerging idea, to support complex decisions, and to transgress the many quality gates that are associated with innovation practices. As people project their various skills, perspectives, and concerns into this solution space, they are able to negotiate ideas and reach a consensus. This joint decision-making and negotiating practice entails communal persuading and gatekeeping whereby involved innovators commonly use artifacts as a reference or prospect for the envisaged solution. Interpreting the practice of *negotiating solution paths* through the artifact lenses reveals that innovators use artifacts to coordinate their collaborative discovery around activity objects. While boundary objects are essential to facilitate collaboration and create the scaffold around which innovators bring their mental models into alignment, activity objects can also be used to support collective decision-making and negotiate solution paths. Unlike boundary objects, which can preserve an idea's integrity in different contexts, activity objects are necessarily partial pieces of a puzzle, elusive for any of the involved collaborators, and they require discourse and mutual adjustment of conceptions. Innovators at BITS and CustomSoft negotiated solution paths in a creative way by identifying and resolving conflicts with artifacts, be it a well-prepared decision matrix in excel, a management summary in PowerPoint, a prototype discussed in a workshop, or an idea wiki. Such activity objects share some commonalities with epistemic objects in that they both direct practices and motivate collaboration through their unfinished nature. But in addition to that, they can be seen as shared problem spaces into which people project their various perspectives to negotiate an object or objective (Nicolini et al. 2012).

Practice 4: Crafting an Idea

In this fourth practice, *crafting an idea*, innovators employ measures that advance the process of idea materialization. This practice has the goal to execute the previously agreed upon actions in a targeted manner. From studying BITS and CustomSoft, we learned that the targeted execution of an idea stands and falls with the extent to which those who realize it are willing and able to master their craft. While we would readily confirm that most employees at both companies are creative and have many ideas, it is harder to estimate how many people have the necessary appetite and dedication to take the idea all the way to the end. One way participants at BITS and CustomSoft tend to think of execution is to compare innovative work with a craft: *"It is really simply a craft to understand: 'How do I achieve a certain goal with limited resources in manageable time?' [And to] recognize: 'This is an important question and that is an unimportant question; this is a solvable problem and that is an unsolvable problem.'"* [i78, Senior Manager, CustomSoft].

Crafting an idea is a non-linear process, often imbued with uncertainty and fear of failure, requiring experimentation, hacking, tinkering, and trying out what is possible in a given situation. We observed that innovators learn while they are in flow and make their way through the idea while executing it, sometimes referring to this practice as innovating-by-doing or trial-and-error. For instance, one member of the mobile banking project compares prototyping with Lego: "*You add one or two bricks, remove some others, refine a whole chunk, then start again with a new plate. […] The whole idea is only a sketch until you build a prototype and validate it with someone who has the business knowledge. But unless you create something tangible, you will never get to the next level."* [i10, Business Analysts, BITS]. This participant points to how the maturity of the presented artifacts influences the quality of the feedback that one can obtain. Here, crafting an idea required the project team to dedicate itself toward creating a sufficiently persuading artifact (in this case, a software prototype). Of course, this is only a part of the whole story.

What is much more difficult to capture through after-the-fact interviews are the actual work practices behind crafting an idea. These practices are to a large extent mediated by a whole ecology of artifacts that people often note only subconsciously, if at all. This becomes much more apparent in the following field note from a participant observation at BITS:

> "*In the BITS office with the Web Self-Service project team, I follow a conversation between the team head T. and software developer M. who try to understand why the IDE (integrated development environment) keeps throwing a runtime exception at M.'s test environment who currently develops a central module. They open and argue around a wiki page that contains a whiteboard photograph that illustrates the target architecture of the module from last week's architecture workshop. M. has a conjecture where the problem may lie and walks over to the room's whiteboard to redraw the target architecture and the object lifecycle. They realize that the error must have been introduced with the last update in the persistence layer. T. quickly opens the code review system to inspect the changes that M. made since the last working version of the system. They go back to the whiteboard and revise the target business object design with an additional attribute and an adapted persistence process."* [From field notes; cf. figure 3]

Taken alone, the whiteboard, the wiki page, the IDE, the code review system, and the office room may seem insignificant. In fact, people usually use such mundane artifacts subconsciously, without explicitly reflecting about it. But without these mediating artifacts, crafting the idea would be very difficult. When we later interviewed the team head and software developer, they would not reconstruct the situation with all involved artifacts. In fact, only few participants would mention their IDE as an artifact in an interview since it is so deeply entangled in their everyday work. Only in the case of a breakdown, i.e. when the IDE did not work as expected, did the two participants start to consciously investigate the problem. Thus, addressing such artifacts explicitly helped us to shed more light on the process of idea materialization.

Interpretation: Material Infrastructure in Digital Innovation Practices

Crafting an idea describes how the development of digital innovations emerges from the bottom-up enacted practices of individuals, out of hacking and tinkering. It depends crucially on the targeted execution by skilled individuals. It is a materially mediated activity in that design steps are tinkered and formed from the stack of resources at hand. By allowing innovations to evolve from bottom-up, rather than controlling them through strategic planning from top-down, a company is able to end up with something original (cf. Ciborra,

1992). When innovators craft an idea, they use what is ready-to-hand and embedded locally, mobilizing existing digital and physical artifacts. By recombining and re-employing these artifacts at hand, people are able to craft innovative solutions for real problems.

Innovative developments are often characterized by continuously considering what existing artifacts are available and then what can be developed within the boundaries provided by those assets (Leonardi, 2011). It is important to note that these assets can both afford and constrain innovation. Consider an architect who develops the blueprint for a new house that is to be built; the realization of the blueprint depends crucially on the artifacts at hand, such as cost and availability of local building material, environmental conditions, statics, contemporary architecture style, and the expertise of skilled workers. That being said, it comes evident that innovative developments are a matter of crafting ideas in a targeted manner. The material infrastructure lens (Nicolini et al., 2012; Star and Ruhleder, 1996) helps to understand the practice of crafting an idea. Material infrastructure remains subtly, yet importantly, in the background and people often to not even consciously note that they it. In digital innovation practices, however, the absence of the material infrastructure, composed of whiteboards, laptops, screens, integrated development environments (IDEs), wikis, office rooms, would make it next to impossible to create further artifacts that may once function boundary objects, activity objects, and epistemic objects. It is therefore helpful to explicitly embrace various kinds of artifacts in an analysis of innovation practices.

Discussion

In the previous section, we studied the digital innovation practices at two Swiss software companies by focusing on the artifacts they used as part of these practices. Based on our comprehensive data set, we were able to identify a number of artifacts whose respective role in digital innovation practices we discussed building on multiple artifact lenses, thus, answering our first research question: *What role do artifacts play in digital innovation practices?*

Placing a stronger focus on artifacts helped us furthermore to identify and characterize the actual innovation practices and to answer our second research question: *Through which practices do people enact digital innovation in organizations?* We have illustrated four such practices, namely people make sense of ideas, align mental models, negotiate solution paths, and craft ideas. Next, we suggest a conceptual model in figure 4 that helps to set the four practices in relation to each other.

Towards a Practice-based Model of Digital Innovation

When *making sense of an idea*, innovators strive for a clearer understanding of an idea by constructing epistemic objects. Thereby, they identify uncertainties (e.g. open questions or issues that need clarification) and conflicts (e.g. different and mutually exclusive possible viewpoints, competition for resources). These flow into *aligning mental models* and *negotiating solution paths,* respectively. In the former, stakeholders that are involved in the innovation endeavor develop a shared understanding by constructing boundary objects. In the latter, the innovation teams narrow down the possible solution space and agree on necessary actions by constructing activity objects. In both practices, innovators identify and mutually exchange solution options, whereby the output of *aligning mental models* is a shared understanding of and the output of *negotiating solution paths* is a decision on these, respectively. Both outputs flow into *crafting an idea*, where innovators employ necessary measures to advance idea materialization by transforming the available material infrastructure in a targeted manner. In a learning by doing fashion, the innovator thereby obtains refined ideas, which again flow into *making sense of an idea*, where the whole process starts anew.

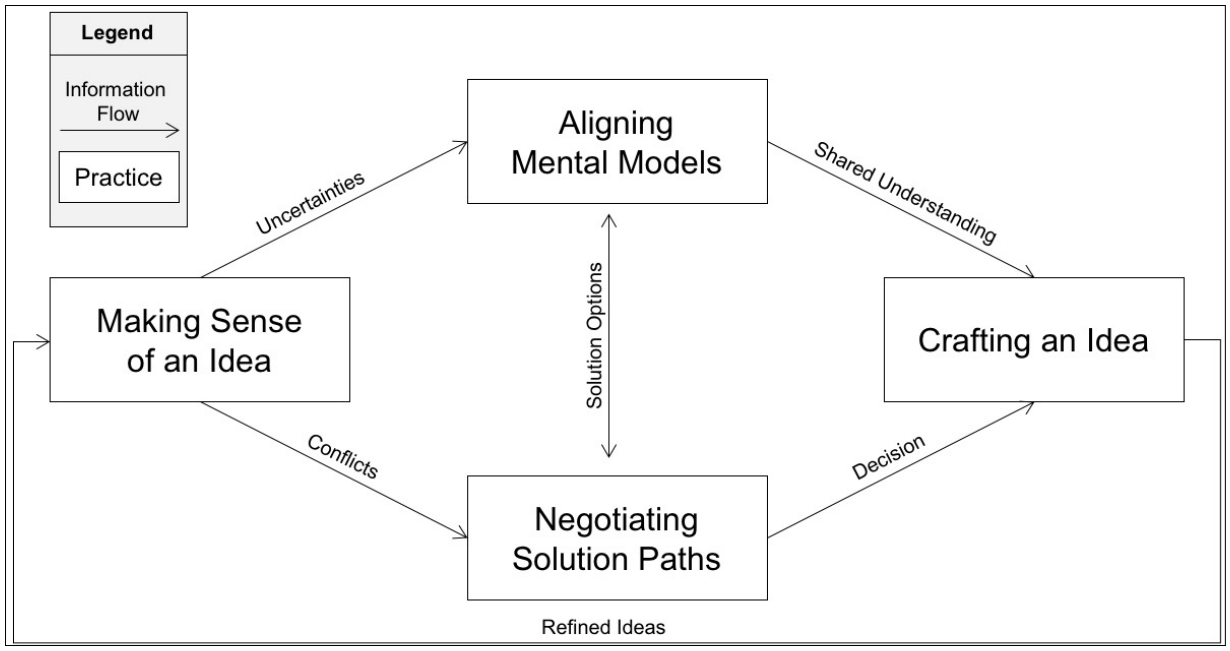

Figure 4: Practice-based Model of Digital Innovation

Illustrating the relationships between the four identified digital innovation practices foregrounds the bottom-up characteristics of digital innovation. The model illustrates an innovation process that reflects the open-ended, emergent, and serendipitous character of digital innovation. Taken together, these four practices form an iterative and incremental cycle that extends the linear process perspective on innovation that prevails in existing innovation management literature (e.g. Chesbrough, 2003; Desouza, 2011; Fichman et al., 2014; Tidd and Bessant, 2011). Our study suggests that the phases usually overlap and the interdependencies are much more complex than they appear in the linear path models of the linear process perspective. Our results show that, in the two studied cases, innovators perceived digital innovation phases as strongly interconnected. This observation for the innovation process is in line with the general observation of (Nambisan et al., 2017) that companies develop into decentralized innovation collectives with diverse goals, motives and capabilities. The suggested model adds to this picture in that it is not only artifact based, but also shows the huge mediating impact of artifacts. At same time, the innovation process resides within people's activities (Ciriello and Richter, 2015), which are in their turn supported by objects.

IS scholars with an interest in understanding and improving digital innovation may draw on this contribution to better understand the environmental conditions under which artifacts play different roles that require different supporting measures (cf. Ciriello et al., 2016). Consequently, it is beneficial to analyze and design artifacts to meet the respective requirements of the underlying practices, for which to design social and technical innovation support. Furthermore, we found a process that is self-referential in that any idea lets innovators encounter new problems, which in turn lead to more refined ideas when solved. This conceptualizes digital innovation as an artifact-mediated human practice with alternating sequences of individual practices and group practices involving continuous learning, improvisation, and trial-and-error. Our suggested practice-based model of digital innovation offers a nuanced perspective on how artifacts can play different roles more or less well, depending on the practice in which they are used. This directly addresses Nicolini et al.'s (2012) call to research not only the plural role of artifacts, but also the contextual factors that trigger transitions in their role. Namely, depending on whether the current situation requires making sense of an idea, aligning mental models, negotiating solution paths, or crafting an idea, the same artifact may change its role back and forth between epistemic object, activity object, boundary object, and material infrastructure, respectively. The provided interpretation of each practice focuses on this changing role of artifacts and thereby relates to the first research question in this paper, namely *what role do artifacts play in digital innovation practices?* The practice-based model foregrounds that one single view on artifacts does not suffice to understand how various artifacts mediate and facilitate digital innovation practices differently. Rather more, a nuanced understanding of the multifaceted constellations of people, practices, and tools is necessary to allow digital innovations to emerge.

Implications for Theory and Practice

Organizations with an interest in facilitating digital innovation should enable employees to participate in the innovation process by providing an environment where they can enact the here identified practices with readily available artifacts at hand. We suggest future research to also think of the broader shift in perspective, namely from managing and controlling top-down specified innovation processes towards facilitating and enabling bottom-up emerging innovation practices. Our study suggests that managing digital innovation means a radical departure from classical IT project management approaches, which mostly rely on project management methods that are not specific to IT (cf. Yoo, 2013). By injecting digital artifacts into innovation practices, the practices themselves inherit characteristics of digital artifacts, such as programmability, traceability, and malleability (Yoo et al. 2010).

We contribute to this ongoing discourse in IS literature by helping to understand the important role of practices and artifacts in digital innovation. Ever more companies place a stronger focus on innovating and thereby face various new opportunities but also new challenges (Tidd and Bessant, 2011). Companies struggle with shortened product cycles and high demands on time to market (Christensen, 1997), increased competition through globally networked alliances (Chesbrough, 2003), and last but not least strong competition for skilled and creative employees (Desouza, 2011). This increases the pressure on employees to act entrepreneurial within the boundaries of their organization, which involves breaking free from established thinking patterns, dealing with high degrees of uncertainty, and overcoming resistance to change (Desouza, 2011). Our study illustrates ways in which companies can support employees to better realize ideas, and how employees can execute the necessary steps. Our practice-based model is a starting point for designing social and technical innovation support, and for analyzing why many well-intentioned innovation management approaches often do not result in well-executed innovation practices.

Our study also contributes to understanding the role of artifacts in digital innovation practices. The practice-based model offers a rich picture of how various kinds of artifacts can support innovation practices in different ways. Researchers with an interest in understanding and improving innovation practices in the software industry may draw on this contribution to better understand the context factors that influence the outcome of innovative software projects. We show that the outcome of innovative software projects depends crucially on the ability of innovating people to skillfully execute innovation practices through the targeted use of various artifacts. Consequently, analyzing and designing artifacts that meet the requirements of the here identified innovation practices is beneficial for better supporting creativity and innovativeness in industrial software development processes. The suggested model offers a nuanced perspective on the changing roles of artifacts throughout the innovation process.

Limitations and Outlook

We identified and illustrated a set of digital innovation practices using qualitative methods and inductive theory building to explore concepts and their interrelations. However, we did not develop metrics to measure the suggested interrelations and their relative effect sizes. Subsequent quantitative studies like experiments or surveys could help to take the model a step further.

Moreover, we focus our study on two software companies that are both culturally innovative organizations, yet not necessarily leading edge. Whereas our insights offer possibilities to deeper understand digital innovation practices from an artifact perspective, they alone do not offer comprehensive prescriptions on how these practices should be supported ideally. Further research could build on our contribution and examine how leading innovative companies engage in the here identified practices to develop “best” practices and structured guidance for innovation.

We see our contribution foremost in the analysis of innovation practices in two software firms, out of which we develop a practice-based model, whereby the specific character of digital innovation becomes particularly apparent in the use of IT artifacts, as described in the 'interpretation' sections after each practice. We studied innovation practices in software firms, so our research domain is digital innovation, where characteristics of IT play an important role. While an application of our practice-based model beyond the domain of digital innovation is thinkable, there may be some limitations to the external validity of our findings. We purposefully chose a medium level of abstraction to describe the innovation practices in depth while also offering opportunities for generalization. Studying other types of software companies or maybe even studying companies from other industries could help to understand in which contexts our model

applies. We hope that our study inspires follow-up studies that look at these practices in other contexts, such as architects, designers, engineers, or teachers.

Conclusion

This paper explores digital innovation from a practice perspective, focusing on the artifacts that employees use as part of their innovation practices. Drawing on an in-depth case study at two Swiss software companies, our analysis shows how employees use a variety of artifacts, depending on whether they pursue a clearer understanding of an idea for themselves, create a shared understanding among relevant stakeholders, negotiate solution paths to narrow down the possible solution space, or advance the process of idea materialization through targeted execution of necessary actions. In this regard, this paper specifies artifact use practices in an innovation context and, thereby, clarifies the role of artifacts in digital innovation practices. In times where new digital technologies play an increasingly important role and gain growing research attention (Yoo et al., 2010, 2012), one should bear in mind the major role of artifacts and how they mediate social interaction (Nicolini et al., 2012).

The present study contributes a practice-based model of digital innovation to that discourse. This model reflects the bottom-up emergent nature of digital innovation in a corporate environment, enacted in the individual practices of employees; it specifies the conditions under which artifacts change roles; it provides rich insight into how people enact digital innovation practices with artifacts; and it provides a practical example of how the framework by Nicolini et al. (2012) can be applied.

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