The Paradoxical Effects of Digital Artifacts on Innovation Practices

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Abstract

Digital artifacts are increasingly used for supporting innovation practices, implying a growing need to better understand their role in different contexts. In this paper, we study how digital artifacts enable and constrain innovation practices by means of an in-depth, multi-year qualitative field study at a software firm. Analyzing the usage of PowerPoint, as a dominant digital innovation artifact, we identify three paradoxes – conflicting yet interdependent tensions of digital artifacts in innovation practices: 1) *Freedom and Captivity*, 2) *Clarity and Ambiguity*, and 3) *Scarcity and Abundance*. Via a dialectic synthesis of the three paradoxes and an extension to modeling tools, we develop a substantive theory of the paradoxical effects of digital artifacts on innovation practices. We discuss theoretical implications for research on affordances and outline a path for research on IT paradoxes. We also offer practical implications by illustrating the paradoxical effects of using digital innovation artifacts and suggesting appropriate coping strategies.

Keywords: Paradox, Innovation practices, Digital, Artifact, Affordances, Qualitative field study, PowerPoint, Modeling Tools

1 Introduction

Many companies rely on the creation of new digital products and services to succeed in today's increasingly digitized world (Fichman et al., 2014; Nambisan et al., 2017). With their objective of supporting employees to create digital innovations, companies need to understand the fundamental changes imposed by new kinds of information technology (IT) and the associated changing nature of innovation (Desouza, 2011; Yoo et al., 2012, 2010). A logical starting point for understanding these evolving digital innovation practices is to study how innovators in organizations use digital artifacts to form, evolve, and add to a shared innovation agenda (Ciriello et al., 2017a). As these digital artifacts allow space- and time-independent collaboration on innovations, understanding their mediating role becomes ever more important (Nambisan et al., 2017).

Closely related to this, scholars have argued that malleable and flexible digital artifacts increasingly contribute to the ongoing formation and transformation of organizational practices, with a host of far-reaching consequences that we do not yet fully understand (Faulkner and Runde, 2013). Only when we understand the relationship between the characteristics of a tool and the underlying usage practices, we will be able to fully understand the positive or negative consequences of its use (Orlikowski, 2007).

It is in line with these calls for action that we suggest studying digital innovation artifacts with certain characteristics that seem to have ambivalent effects on innovation practices. Through dialectic synthesis, based on related literature and a set of qualitative data collected at an innovating software firm, we provide a rich understanding of the tension that comes into play when using digital artifacts in innovation practices. By examining in parallel how digital artifacts enable and constrain innovation practices, we show that their beneficial and detrimental effects cannot be regarded separately. This is the analytical focus of this paper, in which we raise and address the guiding research question:

RQ: How do digital artifacts enable and constrain innovation practices?

The contribution of this paper is a substantive theory of the paradoxical effects of digital artifacts on innovation practices. Substantive theory refers to theory that is moderately abstract, is developed based on analysis of observations for a specific area of inquiry, and is particularly important for practice disciplines (Gregor, 2006). Our substantive theory provides rich insight into the role of digital artifacts in innovation practices. Through dialectic synthesis, we critically reflect on the paradoxical effects of PowerPoint - as an example for an arguably dominant digital innovation artifact - on innovation practices. This allows us to illustrate the contradictory ambivalences, i.e. paradoxes, that innovators experience when using digital innovation artifacts, and to show how innovators cope with these paradoxes. We demonstrate the transferability of our substantive theory by means of a comparative analysis with modeling tools. From this, we hypothesize that any digital artifact with similar affordances like PowerPoint may give rise to similar paradoxical tensions between Freedom and Captivity, Clarity and Ambiguity, and Scarcity and Abundance. We discuss theoretical implications for the study of digital artifacts and set the stage for further research on their paradoxical effects. A practical contribution is that innovators and innovation managers can use these paradoxes as a guideline to understand how using digital artifacts with similar kinds of affordances can enable and constrain innovation practices.

In the remainder of this paper, we summarize prior work on digital artifacts and describe PowerPoint and its affordances with regards to innovation practices in Section 2. We introduce the paradox lens we adopt to theorize the ambivalent role of digital artifacts in Section 3. We then give detailed insights into our research approach in Section 4, providing context on the qualitative data set we gathered in our extensive field study, consisting of 64 interviews, 116 slide decks, and 196 days of participant observation, illustrating how its analysis helped us to theorize paradoxes of digital innovation artifacts. Section 5 sets out our results – three paradoxes and ways of coping with them. Section 6 contains a theoretical integration and discussion of the implications of our study. In Section 7, we conclude by summarizing the key takeaways and pointing to areas of future work.

2. A Paradox Perspective on Digital Artifacts

We adopt a paradox perspective to study the ambivalent effects of digital artifacts on innovation practices. Schad et al. (2016, p. 10) define paradox as "persistent contradiction between interdependent elements". This definition emphasizes two properties of a paradox: 1) contradiction between two underlying propositions (A and B) that seem plausible

individually but impossible when juxtaposed, and 2) the necessity of responding with coping strategies that embrace the tension simultaneously (Smith and Lewis, 2011).

Poole and Van de Ven (1989, p. 565) advocate four such coping strategies:
1) acceptance – keeping A and B separate and their contrasts appreciated,
2) spatial separation – situating A and B at two different levels of analysis,
3) temporal separation – switching between A and B in the same location at different points in time,
4) synthesis – finding a new perspective that eliminates the opposition between A and B (cf. Smith and Lewis, 2011, p. 385).

In recent years, paradoxes of our increasingly complex social world attract considerable attention in management studies and organization studies (Smith et al., 2017). For instance, scholars have identified paradoxical tensions in organizational processes of exploration and exploitation (Andriopoulos and Lewis, 2009; Raisch and Zimmermann, 2017; Smith, 2014; Tushman and O'Reilly III, 1996), in knowledge workers' conflicting demands of personal autonomy and professional commitment (Mazmanian et al., 2013), and in contradictory technology affordances that interact to balance, rebalance, and provide feedback in online knowledge production (Faraj et al., 2011).

Despite this growing interest, paradoxes remain a nascent field of study, in which much work is interpretive and exploratory (Smith et al., 2017). Unlike logical paradoxes, which have deep historical roots in Eastern and Western philosophical traditions, socially constructed paradoxes oppose elements that are often somewhat vague, where contradictory elements are embedded in material artifacts, practices, and arrangements (Hargrave and Van de Ven, 2017), and tension between incompatible propositions in the social world must be considered, rather than dealing with logical contradictions (Poole and Van de Ven, 1989). Instead of striving for harmony and consistency, looking for theoretical tension and using it in a creative way creates an opportunity to develop more encompassing theories that capitalize on the duality and generative force of paradoxical tension (Eisenhardt, 2000; Hargrave and Van de Ven, 2017; Poole and Van de Ven, 1989).

Coping with such paradoxical tensions requires people to develop special cognitive abilities, which have been described as *paradoxical cognition* (Lewis, 2000), *both/and* thinking (Quinn et al., 2006), and *either/and* thinking (Jing and Van de Ven, 2014; Li, 2012), indicating that the paradoxes to be dealt with consist of tensions between distinct yet unified opposed elements that people can often only cope with rather than resolve (Hargrave and Van de Ven, 2017). Smith and Lewis (2011) describe a dynamic equilibrium model in which managers engage in a process of synergy to purposefully iterate between contradictory elements in order to avoid "paralyzing and often vicious cycles" and instead initiate "virtuous cycles" (p. 761).

In information systems (IS) research, paradoxes have been used as rhetorical devices to create appealing tension that exposes novel insights of the irony and dilemma that digital artifacts embody. For instance, IS scholars have identified paradoxical tensions in the growing and stagnating productivity of IT (Brynjolfsson, 1993), in the promoting and impeding role of IT in organizational change (Robey and Boudreau, 1999), in the strategic value and low status of IT management (Avison et al., 1999), in the intended and unintended

consequences of mobile technology usage (Jarvenpaa and Lang, 2005), in the conflicting demands of personalization and privacy in online consumer profiling (Awad and Krishnan, 2006), in the physical organization of virtual team work (Dubé and Robey, 2009), and in the ambidextrous management of IT transformation programs (Gregory et al., 2015).
For the context of digital infrastructure, Tilson et al. (2010) discuss the paradoxical nature of change and control. Referring to Ford and Backoff (1988), who argue that digital infrastructure appears stable only when opposite tendencies are brought into recognizable proximity through reflection or interaction, Tilson et al. (2010) advocate a duality view on paradoxes. This implies a need for both stability and flexibility, alongside control and autonomy. We therefore suggest adopting a paradox perspective to illustrate and make sense of the ambivalent practices enabled by digital artifacts. Our dialectic examination of three paradoxes, which ends in a synthesis, can be seen as such a duality view, as it later "enables us to dissolve and transcend" the paradoxical effects of digital artifact usage (Farjoun, 2010, p. 202).

3 Literature Background

We start this section by introducing our research domain – innovation practices – and discussing the important role of digital artifacts in such practices. Next, we focus on PowerPoint as a dominant digital innovation artifact, and especially its affordances in the context of innovation practices.

3.1 Digital Innovation Artifacts

The development of new products and services, enabled by software or resulting in new software, has become essential for companies to compete and lead in today's digitized world (Fichman et al., 2014; Nambisan et al., 2017; Yoo et al., 2012). This leads to a growing interest in understanding innovation practices in the software industry. In software firms, innovation is an iterative, interactive, and feedback-intensive process that requires exchanging ideas between different kinds of stakeholders who engage in challenging innovation practices that require creativity (Neyer et al., 2009).

Many of these innovation practices, such as ideating, sketching, modeling, or prototyping software systems to collaborate and persuade decision-makers, build strongly on using digital artifacts. Such usage is widely considered to be a fundamental aspect of any practice (Carlile et al., 2013). 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,' referring to the role of artifacts in practice. In line with this view, practice-based studies in the information systems discipline 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) states, a practice perspective unveils that "materiality is integral to organizing, positing that the social and the material are *constitutive*ly entangled in everyday life" (p. 1437, italics in original).

In this paper, the term *digital innovation artifact* refers to any underspecified representation of an envisaged new software product (Ciriello et al., 2017a). A fundamental characteristic of any digital innovation artifact (going forward just *artifact*) is that it is always practice-oriented. The artifact can be the means and/or the end of a practice, but the underlying practice determines its role (Kaptelinin and Nardi, 2009). Analyzing artifact usage yields an opportunity to better understand the underlying practices (Riemer and Johnston, 2014). In innovation practices, artifacts can manifest as abstract ideas or concepts and are therefore often emergent, unfinished, and partial (Ciriello et al., 2014). 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, advancing thinking and inspiring further development (Rheinberger, 1997). An artifact can also be used to collect feedback and build a social coalition for further developing the innovation. As such, the artifact can be an important tool to facilitate communication and decision-making (Ciriello et al., 2017b).

3.2 PowerPoint: A Dominant Digital Innovation Artifact

In the class of the abovementioned digital innovation artifacts, PowerPoint has played a dominant role in many companies over the last decades. With more than one billion installations, millions of slides produced every day, and several hundred presentations every second, PowerPoint has become an indispensable tool for knowledge workers around the globe (Parks, 2012). Over the last decades, PowerPoint usage has continuously expanded to settings that stretch far from its originally intended purpose, and scholars argue that this expansion will continue in the future (Kernbach et al., 2015; Schoeneborn, 2013).

Studies have shown that people often use PowerPoint not only for the original purpose of facilitating presentations, but also for other purposes, such as brainstorming, documentation, modeling, or even prototyping (Schoeneborn, 2013; Yates and Orlikowski, 2007). When using PowerPoint in settings beyond the classic presentation, users experience a variety of intended and unintended consequences that are not yet well-understood. For instance, scholars have argued that the enforced bullet point logic suggests inaccurate levels of simplicity and prevents critical thinking (Gabriel, 2008; Tufte, 2003); that PowerPoint slides, which often serve the dual purpose of documentation and presentation, fail to satisfy the information requirements of either (Schoeneborn, 2013; Yates and Orlikowski, 2007); and that the frontal presentation style reduces active discussion in favor of passive consumption (Kernbach et al., 2015).

In many of the abovementioned innovation practices, such as ideating, sketching, modeling, or prototyping, IT professionals tend to prefer using general-purpose tools, which provide them with greater freedom of expression, over single-purpose tools that enforce uniformity (Cherubini et al., 2007). PowerPoint is therefore often used for software modeling, even in technical domains, as it supports unconstrained sketching and does not enforce any predefined modeling notation except for the available basic shapes, such as boxes and arrows (Ossher et al., 2010). Especially in the creative process of generating, developing and communicating ideas through sketches, which is essential throughout software design, modeling tools are only effective if they do not distract from the core sketching experience and let users stay in their natural creative flow, rather than interrupting it (Bellamy et al.,

2011). Dedicated modeling tools usually require much effort to learn the notation and cause premature commitment by imposing inappropriate levels of detail and order. In turn, PowerPoint is free of constraints imposed by metamodels, has broader applicability, is easier to learn, and allows the user to choose the order of development, enabling meaning to evolve as content is created (Ossher et al., 2010).

The downside of software modeling with applications like PowerPoint is that the lack of semantic representability also implies lack of semantic support. For instance, boxes and arrows have no semantic representation as entity relationships, but only as graphic objects (Ossher et al., 2010). As a result, there is no easy way to update the presentations and diagrams (Ossher et al., 2010), with the result that sketches are disconnected artifacts that cannot be stored, shared, or versioned easily, nor can they be linked to other artifacts conveniently (Bellamy et al., 2011). In applications like PowerPoint, consistency management is a manual and cumbersome task, as a single consistent change in style or terminology of an element may require many actions throughout many documents (Ossher et al., 2010).

Nevertheless, the usage of PowerPoint and similar digital innovation artifacts still increases, as they can be very persuasive. The aesthetics of an illustrative slide play a crucial role in persuading relevant stakeholders with different roles and educational backgrounds, especially if the creator manages to illustrate a clear benefit in a feasible way (Carlile, 2002). For instance, studies have shown that PowerPoint can persuasively display things that do not yet exist in reality (Kaplan, 2011; Stark and Paravel, 2008). While this may be useful for communicating envisaged solutions, PowerPoint presentations also tend to signal a preparedness that overshadows the content's degree of maturity (Tufte, 2003). Problems may arise when PowerPoint presentations do not provide sufficient information on the idea’s actual state per se, especially when the author is not present. Misinterpretations may also result from dissonant genre expectations (Yates and Orlikowski, 2007). For instance, PowerPoint documents that are used for the dual purpose of presentations and project reports tend to leave the information requirements of both purposes unsatisfied (Schoeneborn, 2013).

Scholars have argued that PowerPoint contributes to the ongoing democratization of innovation by giving people at all hierarchy levels a voice through their creation and dissemination of PowerPoint slides (Kaplan, 2011). As PowerPoint approaches the status of a universal business language (Gabriel, 2008; Schoeneborn, 2013), the widespread use of PowerPoint allows innovators to start presenting or discussing their ideas without the necessity to establish a common understanding of the discussion format. PowerPoint is pre-installed on most office computers, implying that everyone can easily access and use it. The digital presentations can also be shared with others without many intermediate steps, and through a variety of online channels, such as chat, email, or wiki.

Others have argued that the routinized use of PowerPoint may constrain creative practices such as freehand drawing or simply talking to each other (Gabriel, 2008). This can be particularly detrimental when using PowerPoint in early innovation phases. Studies have shown that the forced linearity of a PowerPoint presentation leads to a tendency to defer questions to the end, thereby reducing the speaker’s responsiveness to the audience (Yates

and Orlikowski, 2007), and constraining fruitful discussions, improvisations, and inventiveness (Gabriel, 2008).

In a nutshell, the phenomenon of PowerPoint usage is widespread in many organizations, has persisted for decades, and will likely expand in the future (Schoeneborn, 2013) despite the negative consequences that are well-documented in the abovementioned literature. Scholars have argued that PowerPoint's beneficial and detrimental effects need to be studied in parallel to provide an accurate appraisal (Kaplan, 2011). Studying PowerPoint usage can yield a rich understanding of the underlying practice in which it is used (Fichman et al., 2014; Leonardi, 2011; Orlikowski, 2007; Riemer and Johnston, 2014). It is in line with these calls for action that we dialectically examine PowerPoint usage in innovation practices, as we can expect such a study to yield insights about the general nature of digital innovation artifacts.

3.3 Affordances of PowerPoint

If we want to clarify the role of digital artifacts in innovation practices, it is first necessary to identify their characteristics in this context. An affordance perspective is appropriate for this purpose, as it allows examining the characteristics of a technological tool in relation to a specific practice. Gibson (1977) introduced the notion of affordances to study action possibilities for animals (including humans) in relation to the properties of a given environment. In information systems (IS) research, the affordance perspective has been used to study the effects of digital artifacts in the context of practices. Markus and Silver (2008) define functional affordances as "possibilities for goal-oriented action afforded to specified user groups by technical objects" (p. 622).

One insight offered by the affordance perspective is that material properties that exist in technical objects are contingent on, but not constitutive of, users' perception, interpretation, and appropriation in a specific practice (Orlikowski, 2007; Orlikowski and Scott, 2008; Zheng and Yu, 2014). While technical objects exist independently of users' perceptions, their affordances are "not reducible to their material constitution but are inextricably bound up with specific, historically situated modes of engagement and ways of life" (Bloomfield et al., 2010, p. 415). This implies that affordances arise from "actions in the world″ in which they are enacted, requiring us to understand "how the specific action unfolds in that unique moment and situation, whom and what it enrolls, and how it affects the world" (Faraj and Azad, 2012, p. 255). It has further been argued that the enabling and constraining effects of digital artifacts cannot be considered as alternatives (a dualism), but rather as two sides of the same coin (a duality) (Yates and Orlikowski, 2007). As people pursue their goals with the digital artifacts they use to perform a task, they actively construct perceptual affordances with enabling and constraining effects (Leonardi, 2011). To make sense of a digital innovation artifact, it is necessary to dialectically examine in parallel its enabling and constraining effects in relation to a specific practice. We therefore focus our analysis of on the duality of PowerPoint's enabling and constraining effects on innovation practices.

From reviewing prior empirical studies and literature reviews, we identified the following PowerPoint affordances that can help us to better understand its role in an innovation context: *1) presentability, 2) animatability, 3) sequentiality, 4) modularity, 5) malleability, 6) digitality, and 7) integrability*.

Presentability: PowerPoint slides can be projected onto a wall. Many modern meeting rooms or lecture halls are equipped with a projector specifically for this purpose. A (semi-)dark environment is usually necessary to visibly display the slides (Kernbach et al., 2015). Only the presenter can control the slideshow, by using a keyboard or a remote control. The slides cannot be edited in presentation mode, although PowerPoint allows a presenter view that displays editable presentation notes on a screen separate from the presenting computer.

Animatability: Various animation effects can augment transitions in the slideshow in presentation mode. These include slide transition effects, such as sliding or fading slides in and out, as well as object animation, such as flying objects in and out, rotating objects, and path animation of objects (Kernbach et al., 2015).

Sequentiality: The PowerPoint slide deck is an ordered, potentially unlimited, serial sequence of slides. In standard editing mode, the miniature sidebar may allow jumping to the n-th slide with relative ease. But in presentation mode, people usually only move back or forward one slide after another (Tufte, 2003), as jumping to the n-th slide would require memorizing the respective slide number and type it in, followed by enter – a feature that many PowerPoint users are not aware of.

Modularity: As a digital artifact, PowerPoint allows the combination and recombination of loosely coupled components (Yoo et al., 2012) in a slide deck. Objects in PowerPoint, as well as slides containing them, can be transferred easily to another PowerPoint slide deck, to another place in the same slide set, or to a variety of other Microsoft Office platforms (e.g. Word, Excel, or OneNote). This requires a simple copy-paste operation, as long as the supported software is used.

Malleability: Although originally intended broadly as a software program for editing and presenting slides, PowerPoint does not prescribe narrowly defined use practices and can therefore be characterized as malleable end-user software (Richter and Riemer, 2013). The standard editing mode is generally flexible, and a PowerPoint slide may contain a variety of objects, including free text, lists, comments, presentation notes, formulas, links, graphics, images, shapes, tables, diagrams, audio, and video. The user is only constrained by the available space per slide and the limited set of predefined shapes to choose from.

Digitality: While a PowerPoint slide deck relies on a certain physical infrastructure for its execution (such as keyboard, mouse, computer, screen, projector, wall, or remote control), PowerPoint itself is a purely digital artifact with some of the distinctive characteristics of digital artifacts. For instance, one may produce an unlimited number of perfect copies of PowerPoint slide decks and slides; easily share them via digital media channels, such as email, file systems, web applications, or social media, and store them for an unlimited period of time without expiration (Yoo, 2010; Yoo et al., 2010). In addition, search algorithms can index and find the content of PowerPoint files, enabling storage and retrieval of embedded information.

Integrability: PowerPoint is highly embedded in the digital infrastructure of modern everyday work practices (Schoeneborn, 2013). The software is integrated in the widespread Microsoft Office suite; it runs on multiple operating systems, such as Microsoft Windows and Mac

OSX; and a variety of third party tools are able to open and edit PowerPoint files, such as Apple Keynote, LibreOffice, or Google Docs. In addition, various web applications can display PowerPoint slide decks, such as Slideshare.net, Atlassian Confluence, or Microsoft SharePoint.

4 Research Method

As we expected to gain novel insights from analyzing the use of digital artifacts in innovation practices, we conducted an exploratory field study at a European software firm to obtain a rich understanding of the phenomenon from a participant's perspective. We took an iterative approach to data collection and analysis until a coherent picture emerged, moving back and forth between theories and the different interpretations of the field study material we obtained from social constructions, such as language, shared meaning, documents, tools, and other artifacts (Klein and Myers, 1999). Following principles of interpretive field research (Walsham, 2006, 1995), we iteratively refined emerging concepts through systematic data generation and conceptualization. This paper's specific research question emerged according to our deepening understanding and data conceptualization.

4.1 Relationship with the Research Site

We were initially concerned with understanding and improving employee-driven innovation in the software industry. We therefore studied innovation practices at a large European banking software provider and entered the research site with only a preliminary understanding of digital artifacts in innovation practices. Because the firm wishes to remain anonymous, we'll call it Banking and IT Solutions (BITS). For more than two decades, its business model has been the development, distribution, and operation of its proprietary core banking system. After the executive board became increasingly concerned that the life cycle of this product might peak at some point, BITS took steps to develop various new products and services in the areas of mobile banking, outsourcing, financial services, and consulting. We found work to be largely structured around generating novel solutions to novel problems. Software is at the heart of the products as well as the product development processes of BITS, which qualifies the firm as an appropriate subject for our study.

Our style of involvement with BITS was that of a closely involved researcher having in-depth access to data, issues, and people, who viewed the researcher as one of them, trying to make a valid contribution to the field site (Walsham, 2006). Through this close relationship we had the unique opportunity to study innovation practices closely.

4.2 Data Collection

In collecting our data, we iteratively selected, collected, and analyzed data slices according to what was necessary to construct the emerging theory (Walsham, 2006, 1995). This included obtaining access to different views from selected participants through interviews, collecting and analyzing PowerPoint slide decks, as well as participant observations. The first author of this paper was responsible for collecting all data from BITS to ensure

consistency in the data collection process. Table 1 contains an overview of our applied data collection and analysis techniques, and the following sections provide further explanations.

Table 1 – Overview of data collection and data analysis

Data collection technique	**Appreciative interviewing**	**Artifact analysis**	**Participant observation**
Total collected data	64 interviews, out of which 62 were transcribed and coded Length • total = 3,700 minutes • average = 57.81 minutes • minimum = 19 minutes • maximum = 100 minutes	418 digital innovation artifacts, out of which 116 were PowerPoint slide decks	196 days = 1,666 hours • Passive: workplace observations, meeting attendance, informal contacts • Active: talks, workshops, steering meetings, collaborations
Data analysis technique	Data-driven and theory-driven coding (DeCuir-Gunby et al., 2011)	Genre analysis (Yates and Orlikowski, 2007)	Focus groups (Weber, 1990)

We conducted 64 appreciative interviews, ranging from 19 to 100 minutes, with experts involved in innovation projects at BITS. In appreciative interviewing, questions are framed to evoke reflections on personal experiences, setting the stage for imagining pathways to desirable futures (Schultze and Avital, 2011). The sessions started with a retrospective discovery of the participant's past experiences with using digital innovation artifacts. The interview gradually developed into a prospective discussion of how the use of digital innovation artifacts could be improved to better support innovation practices. By interviewing a wide range of participants with different roles and from different units, we could seek out and document multiple interpretations of the actions under study (Klein and Myers, 1999). We used a semi-structured interview guide to ensure topical focus and consistency, while allowing respondents to freely express their own views (Walsham, 2006). We recorded and transcribed all but two interviews to capture a full description of what was said and facilitate later in-depth analysis, which allowed us to step back and assess the interpretations of the fellow participants in more detail (Walsham, 1995). We wrote detailed interview notes within a day.

Following the idea of triangulation (Silverman, 2006, p. 291), we relied on multiple sources of evidence to integrate multiple interpretations, obtained from interviews, observations, field notes, and documentary material, into a coherent picture (Klein and Myers, 1999). For instance, we collected and analyzed 418 digital innovation artifacts, out of which 116 were PowerPoint slide decks. In addition, we conducted a series of participant observations at formal and informal gatherings, such as meetings, workshops, presentations, fairs, lunches,

and spontaneous meetings, in the context of the innovation projects, spending 196 full days at the research site between 2013 and 2015. Where possible, photographs and field reports complemented the observations.

4.3 Data Analysis and Interpretation

We analyzed the collected data via qualitative data analysis techniques (DeCuir-Gunby et al., 2011; Yates and Orlikowski, 2007). Following the principles of induction, interaction, and multiple iterations, we generated shared meaning through multiple interactions between the authors, and multiple interactions between the authors and the informants from practice (Walsham, 1995). For instance, the authors met weekly in focus groups to analyze data collected by participant observation, moving back and forth between data and theories, interrogating field material to check whether the data supported emerging claims and, conversely, whether theories helped us to make sense of the empirical data (Walsham, 2006). Thereby, we could maintain a critical distance between being involved researchers and the views of people on the research site.

We transcribed the interviews by following a denaturalized approach, focusing on meaning rather than interviewees‘ accents (Weston et al., 2001). We cross-checked the transcriptions among the research team and imported them into the qualitative data analysis software MAXQDA to initiate an iterative and intertwined process of data-driven coding and theory-driven coding (DeCuir-Gunby et al., 2011). Our data-driven coding process started with generating more than 200 tentative data-driven codes which we grouped into more aggregated themes, such as *classes of digital innovation artifacts, technical characteristics of digital innovation artifacts, human practices*, and *innovation process stages*. This was done via a genre analysis (Yates and Orlikowski, 2007) in which we classified the collected PowerPoint slide decks with respect to their *purpose (why?), content (what?), participants (who/m?), form (how?), time (when?),* and *space (where?)*.

In the next phase, we moved back and forth between data-driven and theory-driven coding by making connections between the emerging themes and related literature to construct a more comprehensive scheme (DeCuir-Gunby et al., 2011). We focused the subsequent analysis on reviewing and revising codes in the context of data and theory (ibid). This led us to relate the theory-driven and data-driven codes to one another, through which we identified the paradoxical effects of PowerPoint as the core of our substantive theory. We then integrated the codes into a codebook shown in Table 2.
We gave BITS employees continuous feedback and opportunities to reflect on their own practice (Walsham, 2006). Having key informants from the company review interim study reports enabled them to reflect on our findings and report any discrepancies with their interpretations (ibid). This involved discussing the emerging findings of the study in workshops and presenting them at internal company talks to help practitioners reflect on and improve their own practices. In writing this paper, we oriented ourselves toward the criteria for writing convincing ethnographic texts advocated by Golden-Biddle and Locke (1993) – authenticity, plausibility, and criticality.

Table 2 – Final version of the codebook			
Code category	**PowerPoint Affordances** (Theory-driven codes)	**PowerPoint usage practices** (Data-driven codes)	**Paradoxical Effects of PowerPoint** (Core category)
Code attributes	• Malleability • Sequentiality • Modularity • Presentability • Animatability • Digitality • Integrability	**Personal practice** ○ Simplification ○ Overloading ○ Freely expressing oneself **Interpersonal practice** ○ Embracing flexible interpretations ○ Bargaining ○ Distancing	• **Freedom and Captivity** • **Clarity and Ambiguity** • **Scarcity and Abundance**
Sources	Related literature (cf. Section 2.3)	Collected empirical data (cf. Table 1)	Previous codes

5 Results: How PowerPoint Enables and Constrains Innovation Practices

We have argued from previous literature that PowerPoint is a digital innovation artifact with distinct characteristics that are worth examining in an innovation context. We introduced our in-depth field study of PowerPoint usage in innovation practices at BITS. In this section, we develop three paradoxes from the insights obtained in our field study: 1) *Freedom and Captivity,* 2) *Clarity and Ambiguity,* and 3) *Scarcity and Abundance*. We frame each paradox with a short summary before we dialectically examine it, supporting both its thesis and antithesis with empirically observed practices at BITS. We then synthesize the three paradoxes in the discussion (Section 6).

5.1 Paradox P1 – Freedom and Captivity

From studying innovation practices at BITS, we learned that PowerPoint provides Freedom and Captivity. In this context, freedom is understood as letting people develop and freely express original ideas, while captivity is understood as holding people captive and constraining creative interaction. As a malleable, ready-to-hand, easy-to-use slide editing software program with low entry barriers, innovators use PowerPoint flexibly to adapt to various weakly structured innovation practices, which can enable creative cognition. As a widespread, proprietary, and inhibiting slide presentation software program with high exit

barriers, PowerPoint is deeply entangled in organizational infrastructures, practices, and expectations, which can constrain creative interaction.

Thesis T1 (Freedom): PowerPoint's malleability enables developing and expressing creative ideas freely

PowerPoint's malleability lets people develop visual representations of creative ideas freely without having to conform to narrowly defined visual semantics. Editing slides can be done quickly and easily, and without much prior knowledge of PowerPoint. Through their digitality, PowerPoint slides allow unifying, combining, and merging various kinds of content in one document. Our data shows that this malleability and the possibility of blending different types of content allow a degree of free creative expression that other digital innovation artifacts do not permit. Its widespread use and readiness-to-hand lead people to use PowerPoint in a large variety of innovation practices.

For instance, we observed that innovators freely express themselves using PowerPoint for brainstorming and idea generation. From the beginning of an innovation process, where a creative spark springs to mind, PowerPoint accompanies people in freely expressing ideas:

> *"Every now and then, I open PowerPoint and simply draw. I illustrate my creative process, and when I get the impression that something interesting comes out, I present it 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."*
> [Quote from interview participant 16, further i16, product manager, BITS]

Although PowerPoint is not the only brainstorming tool used at BITS, we could not find a single innovation project of which PowerPoint was not part from an early phase. Even when the first ideas had been generated outside of PowerPoint, there was at least one intermediate step at some point in which PowerPoint was involved to encapsulate the innovative vision:

> "*I often work with mind maps, or in workshops with lists on whiteboards, to brainstorm. I then try to capture the ideas in PowerPoint.*"
> [i7, software architect, BITS]

Such observations were consistent throughout all organizational roles, teams, departments, and projects. The phenomenon of PowerPoint usage in innovation practices was so striking that we felt compelled to better understand and explain why and how all kinds of innovators would use PowerPoint so extensively in such different contexts, although we assumed that there are also other, more sophisticated tools.

Many participants describe PowerPoint as a digital white canvas where they feel relatively unrestricted regarding the type of content they create and how to create it, because it allows content to be created relatively easily. As opposed to purpose-specific tools, which often prescribe more narrow semantics, PowerPoint allows ideas to be expressed more freely, which seems to better fit the vague character of innovation practices. For many participants, PowerPoint is indispensable in practices such as conceptualizing, bargaining, and exchanging ideas:

> "*PowerPoint is the main medium for various artifacts (...). In my role, I need to interact extensively, and PowerPoint is simply good for interaction."*

[i33, program manager, BITS].

This malleability is not confined to using PowerPoint as only a presentation tool. To our surprise, innovators at BITS use PowerPoint in ways that go far beyond its originally intended purpose of editing and presenting slides, such as software modeling and prototyping. Given that we and colleagues at our university institution put considerable effort into teaching our computer science students the goals and benefits of creating semantically clear software diagrams and prototypes with adequate tools, we were eager to find out why many of our graduates seemingly refuse to apply that knowledge in practice.

One participant explains the advantages of modeling in PowerPoint, as opposed to using UML-based tools such as Agilian by Visual Paradigm and Visio by Microsoft:

"*It is the learning curve of using it. In PowerPoint, you just draw your shapes. That is fine and you move on, (...) whereas in Agilian, you have UML. That is one example you have to learn. It is the time you need to invest to do a use case diagram properly. (...) That is why we do not use Agilian. (...) I know Visio is used by other people; not everyone has that. I do not have it. Again, this is used for drawing diagrams that you could probably do (in) PowerPoint."*

[i50, middle manager, BITS].

This use of PowerPoint is not limited to less experienced practitioners who did not learn how to do architectural software diagrams "properly." Modeling in PowerPoint seems institutionally anchored for the following rationale: If it is easier for a larger number of people to model in PowerPoint, and the produced diagrams serve their intended purpose, why bother putting in additional effort (and spending more money) on creating more precise diagrams with specialized, costly, and cumbersome tools? The commercial software products of BITS, for instance, are often documented in numerous PowerPoint slides comprising software diagrams (e.g. use case, activity, sequence, and entity-relationship diagrams) that are essentially all done in PowerPoint. There is even an official internal PowerPoint template that contains more than a hundred predefined shapes for putting together software diagrams (e.g. objects, relations, processes, tables, or messages).

This happens even though BITS selectively recruits university graduates with a strong IT background. Its business model requires BITS to design its software in close collaboration with less technical organizations, such as banks, where formal modeling languages like UML would be of little value, as two senior software architects explain:

"*The UML standard is not adhered to at all, because nobody appreciates it.* (Our drawings) *are simply boxes and arrows, and the discussion around them is important. The drawing is just a reminder of how it was envisaged.*"

[i14, technical lead].

"*At the end of the day, it does not matter whether you model with UML or PowerPoint.”*

[i12, technical lead].

In an innovation context, where the outcome is not yet clearly defined, many participants find it easier and faster to create a rough high-level design in PowerPoint, rather than having a complete design in mind and formally specifying it in UML.

In a nutshell, PowerPoint flexibly adapts to many weakly structured innovation practices, giving innovators freedom of creative expression.

Antithesis AT1 (Captivity): The PowerPoint template, its lack of semantic representability, and social pressure around PowerPoint usage constrain creative interaction

Whereas some participants appreciate that the standard PowerPoint templates allow the quick generation of a relatively professional-looking slideshow, others feel that these templates limit the possibility of designing more creative content according to individual tastes. Innovators in our cases feel constrained by the available space per slide and the limited set of shapes to choose from. PowerPoint also permits abbreviating sentences in a bullet list style:

> "*We had a set of PowerPoint templates that we had to use. But being the slightly rebellious technical writer, (...) I wanted to present something in a certain way, and I was restricted because I had to conform to the template."*
> [i46, technical writer, BITS].

PowerPoint's malleability comes at the cost of limited semantic representability, which limits the possibility of a structured import or export of content. For instance, the innovators in our field study use PowerPoint to mock software diagrams or prototypes, but not to export these objects in such a way that they could continue working on them in a dedicated software program, since it is not possible to import such data from other tools without losing all semantics. PowerPoint’s flexibility backfires when people want to further collaborate:

> "*Just try once to draw a sequence diagram in PowerPoint and you give up. At best, you will get an image (...), but one cannot continue working on it."*
> [i30, software engineer, BITS].

Without the possibility for further computer-aided development on the objects created in PowerPoint, it is impossible to perform important software engineering tasks such as code generation, linking objects semantically across tools or even within the same tool. The seemingly easily created PowerPoint objects become throwaway artifacts with limited reusability:

> "*We always have to start from square one again and create the slides anew. (...) We actually should agree on a tool that everybody uses. (...) One guy prefers Visio, the other prefers Agilian, and what not. If we could only prescribe which tool to use in this company, that would already create value. But everybody has a different opinion about that and if you introduced something, that would already be a change project."*
> *[i7, software architect, BITS].*

Social pressure around PowerPoint further constrains creativity. After many years of deep anchorage in organizational communication, PowerPoint is so deeply entangled in today's everyday office work practices and people's consciousness at BITS that a PowerPoint presentation is the expected format in many situations:

> "*We are so used to having a title and then five bullet points. (...) There is an accepted slide format that is always expected, and if anything is different from that it is almost as if people think, 'Oh, that is not right. What is this?'"*

[i46, technical writer, BITS].

Social pressure at BITS is not only confined to the expectation *that* PowerPoint should be used in many settings but includes expectations about *how* PowerPoint should be used. In an innovation process, it is often necessary to persuade different audiences of one's intended goals in order to pass through various quality gates. Here, PowerPoint remains a preferred choice to visualize the essence of an idea. Given that innovation practices at BITS require the persuasion of a paying customer or other internal or external idea sponsors at some point, a commonly expected setting for a PowerPoint presentation is the sales pitch.

We observed that presenters of PowerPoint slides often develop a selling attitude coupled with a tendency to commercialize and exaggerate. For instance, the BITS management organizes recurring events where employees can give an elevator pitch of their idea in a couple of minutes to acquire funding or other support. The main medium of these sales pitches is, of course, a PowerPoint presentation:

"PowerPoint works well if you need money. Then you need condensed slides. 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 you often don't even pass the first slide.
[i6, technical lead, BITS]

At times, this strong expectation to use PowerPoint in a certain way resembles social coercion. Although many innovators at BITS dislike PowerPoint's afforded captivity, most of them would still not dare to enter an important meeting without having prepared a PowerPoint presentation with the utmost care if they expect a certain outcome:

"I have learned that I am only successful when I adequately illustrate what I want to achieve. [...] *So when I need a decision, I create a PowerPoint presentation, because that is just how it is done here."*
[i8, middle manager, BITS]

Many participants would like to see more willingness to informally discuss unfinished ideas among their colleagues, but PowerPoint creates barriers:

"*The hurdle to present something is very high here, because everyone always expects high-class presentations. It rarely happens that somebody says, 'come and tell me what you think in a 15-minute coffee break*'".
[i6, technical lead, BITS]

Only a few participants stated that they outright reject using PowerPoint to discuss ideas. For instance, because of the distance it develops between creator and content, using PowerPoint can lead to less emotional engagement than drawing with a pencil. While whiteboard, paper, and pencil allow free-form creative sketching and simultaneous drawing and discussing among several people, PowerPoint puts the presenter in a dominating position over the audience, because only one person can control the presentation and edit the document at any given moment. Presenters are tempted to develop overly fixed, closed, and previously defined opinions, because the presentation cannot easily be altered in response to the dynamics of the discussion.

“The PowerPoint, though, that's (…) just the obvious thing in which to show a digest or the bullet point items of an idea. It's more of a one-way mechanism, though, there's no real collaborative element.”
[i46, technical writer, BITS]

In addition, the presenter usually stands close to the projected slides, and at moderate distance from the audience that sits in the necessarily darkened room. This creates a narcotic, distanced atmosphere that can hinder creative interaction and discussion.

5.2 Paradox P2 – Clarity and Ambiguity

It became evident in our field study that PowerPoint plays a paradoxical role in people's decision-making practices at BITS. In some instances, we observed that PowerPoint helps people to clarify ideas when they are required to make a decision on how to proceed. For instance, given the limited space per slide and the strong tendency to abbreviate, people use PowerPoint extensively to structure and simplify ideas, which may lead to well-informed innovation decisions. In other cases, we found that people dilute content when they use PowerPoint, leading to ambiguities that may lead to poor innovation decisions. For instance, given the interpretively flexible nature of semantically ambiguous PowerPoint slides, people were often confronted with misinterpretations. In some instances, people embraced these ambiguities purposefully to stimulate discussion, but often without the desired outcome. We call this the Clarity and Ambiguity Paradox and examine it in the following sections.

Thesis T2 (Clarity): PowerPoint's *modularity* and *sequentiality* enable users to structure thoughts, simplify complex issues, and break down large topic blocks into smaller ones, thereby allowing for a clarification of ideas.

In the section on the Freedom and Captivity Paradox, we touched upon the finding that innovation practices at BITS usually involve alternating sequences of individual and interpersonal practices. Recalling this aspect is a starting point to conceptualizing the Clarity and Ambiguity Paradox.

From studying BITS, we learned that two conditions are essential to facilitate innovation. First, the driving force behind any innovation project is usually an ingenious individual, or a small group of ingenious individuals. These individuals need facilitating conditions to continuously elaborate the idea, make sense of it, and draw out its essential core. Second, coalition building is an integral part of the innovation process, requiring continuous persuasion, collaboration, and alignment with relevant stakeholders.

We observed that people use PowerPoint as a guide to simplify complex content, structure thoughts, and break down large topic blocks. These clarifying qualities of PowerPoint are partly supported by its captivating qualities (cf. AT1). For instance, recall that many participants described how PowerPoint's limited template urges them to abbreviate sentences and create high-level visual illustrations that fit on the available space of the sequential slides. While this constrains some innovators at BITS, others exploit these characteristics as an aid to focus on the essential aspects of an idea:

"I typically begin with mind maps. In general, you start from a problem, and there it begins: How do I formulate what I actually mean? (...) Here, mind maps are quite good to structure the thoughts. (...) In the next step, I often work with charts or diagrams, where I try to visualize certain things for the customer. (Then) I move to a presentation relatively quickly, because you need to get to the point even more."
[i25, middle manager, BITS]

We often observed that innovators at BITS profit in two ways from using PowerPoint. First, they use PowerPoint to create high-level visual illustrations of ideas to advance their individual sense-making process. Second, they present these PowerPoint slides to others, which enables alignment with various stakeholders. The combination contributes to the idea's maturation:

"When it is about bigger things, I typically create a PowerPoint that simply sketches and visualizes the underlying idea. This PowerPoint then has the advantage that you can replicate it, send it around, and view it with different people. This way, you really have something in your hands. (...) And because of that, you can let other people's feedback flow (in) and you can really let your idea grow visually, so to speak. (...) PowerPoint is always the easiest and best way to replicate such stuff."
[i34, project manager, BITS]

The practice of letting an idea "grow visually" in PowerPoint is central in our field study, and it is simplified by PowerPoint's sequentiality and modularity. We often observed that many innovators at BITS exploit PowerPoint's sequentiality to demonstrate how various components build on one another by gradually constructing complex structures slide by slide:

"Once there is a degree of structuration, PowerPoint is a good medium, because one can create graphics relatively fast and simple. […] The PowerPoint slides from (a recent project) would be a positive example. One of the central elements was the object model, which we expanded on extensively. […] We could visualize the object model quite well, and construct additions from one slide to another, whereby we started with the simplest version and built upon it step by step."
[i7, technical lead, BITS]

We often observed this technique, particularly in innovation workshops that participants held with customers or project partners, where the innovators usually help the relevant stakeholders to get a better understanding of the current and future situation by "*showing one process as it is today and then one process with or after the innovation."*
[i6, technical lead, BITS]

It is also possible to use this technique to create visual previews of envisaged software products:

"Show a few screenshots in PowerPoint, indicate with an arrow what will go where, switch to a live demo and then go back to the presentation."
[i23, external partner]

At times, this can take unexpected forms, as some participants develop rather original variations of this technique. People do not only use PowerPoint as a container for

screenshots of a prototype – we observed how participants create mocked prototypes *in* PowerPoint! One participant describes this PowerPoint prototyping:

> *“I can take screenshots of the existing application and take wireframes where I do not have something yet. I file both into PowerPoint and then walk the customer through it step by step. […] This way, customers get an impression of how the final system would look, which is important in that design phase, because they can tell us immediately when they do not need something. When you communicate about these instruments in that phase, you benefit in two ways: You reflect upon your ideas and strike things through that lead to bad usability. In addition, you get customer feedback immediately, and that is good feedback because they see directly where they’re going to.”*
> [i11, technical lead, BITS]

PowerPoint's modularity further permits consolidating different views and helps people reach a common understanding. For instance, various visual illustrations can easily be copy-pasted and modified, so that one can further elaborate the overall picture:

> *"(In our recent project), we first said, 'Okay, everybody who holds a stake in there, everybody should draw (their viewpoint) in a PowerPoint.' Then I took those PowerPoints, pasted all the variations one after another, and then drew my consolidated picture. Then I revised this consolidated picture with the other people. We sat together and drew the PowerPoint together."*
> [i34, project manager, BITS]

Drawing out the essential aspects of an idea is important when aiming to secure ongoing stakeholder commitment. Once a clear message has been shaped, it can be reused and shared. We observed that certain PowerPoint slides are often shown repeatedly in various settings to remind people of the target picture. For instance, one participant compliments a colleague:

> “*His slides are always of that kind that the whole (BITS) gets it. (…) It is always PowerPoint, but what distinguishes his slides from others is pragmatism. [...] It is the kind of (presentation) that other people can also present, and the message is still loud and clear.”*
> [i8, middle manager, BITS]

Sometimes this apparent clarity can also be deceiving. Given their frequent exposure to polished PowerPoint slides, we observed that viewers tend to have the (often false) impression that all the important information is on the slides, often ignoring other valuable knowledge. It is easy to overestimate the maturity of an idea presented in PowerPoint and to underestimate the necessary completion effort. This bias is exacerbated by the circumstance that presenters tend to develop a tendency to oversell and exaggerate. We often observed that innovators were unhappy with ultra-positive feedback about their overly clear PowerPoint presentation, because they would have appreciated more constructive criticism:

> *"At the next architecture meeting, I simply showed the presentation for (my idea). Afterwards, they just said, 'Okay, we do it like that' (...) and I was really excited that it went down so easily. (...) They said, 'You just do it now. We do the architecture exactly as in the presentation'. I just told them, 'Well, great that you have so much trust in me, but do you really know what that means?' I immediately signaled that their envisioned project duration was not realistic."*
> [i31, software architect, BITS]

In a nutshell, PowerPoint plays an important role in the process of clarification, which is essential for decision-making in an innovation process.

Antithesis AT2 (Ambiguity): PowerPoint enables the creation of *semantically ambiguous* and *interpretatively flexible* slides, which can lead to idea ambiguation

We also observed many instances where PowerPoint dilutes content and fosters ambiguities. This is particularly problematic in the often-observed case when a PowerPoint presentation serves as the main (sometimes even the only) project documentation. Even if an inner group of involved people may have managed to obtain a common understanding through PowerPoint, there is no guarantee that the produced PowerPoint slides convey the message unambiguously to all stakeholders.

People at BITS often complained about ambiguous, decontextualized, or simply incomprehensible PowerPoint slides that are sent around via email or archived on intranet platforms:

> *"A presentation is not equal to a document, because in a presentation you are on a higher level of abstraction. If you only write bullet points instead of complete sentences, you are far from being as precise as you should be to create something that later functions as an independent communication device. From a document, I generally expect that I can make sense of it without having to come back to the author. But a slide set is usually linked to the presentation. A slide set sent via email is insufficient. That was unfortunately often the case, that we just received last year's tech talk slides and should do something with them."*
> [i28, external partner]

It is not only problematic to overuse bullet point items instead of text, but the lack of semantic representability makes it very difficult to draw unambiguous and semantically clear diagrams. In contrast with the abovementioned proponents of modeling in PowerPoint, there are opponents with strong opinions on this topic:

> *"I am not one of those people who want to illustrate everything with diagrams. I think that goals, for instance, must be written down in natural language, because it forces the person to be precise. However, I think it is absolutely essential to create diagrams with adequate tools. (...) I have already seen PowerPoint templates for use case diagrams – totally off the mark, but people actually do this."*
> [i8, middle manager, BITS]

Repeated efforts to introduce company-wide guidelines that conform to established modeling standards have failed so far:

> *"Our software actually has a fantastic object model. However, it is not yet established to create a simple UML profile for that, such that one could use standardized tools instead of drawing lines and circles. […] Most people still draw their diagrams with PowerPoint. An object is a circle in PowerPoint! Why not a simple UML profile with a stereotype?*"
> [i21, technical lead, BITS]

In a nutshell, these findings reveal that content created in PowerPoint is to a certain extent always ambiguous. While this may be desirable in some circumstances, for example when having to embrace multiple interpretations, it can be detrimental in others.

5.3 Paradox P3 – Scarcity and Abundance

A third paradoxical situation that emerged from our field study at BITS concerns the management of innovation-related knowledge created and captured in PowerPoint. On the one hand, we found that PowerPoint, by constraining the amount of displayable information and offering restricted functionality, enables the creation of concise, high-level illustrations that fit on one slide. We observed that people at BITS learned to do more with less, making a virtue of the relatively scarce range of PowerPoint functions, seeing its constraints as an exercise to illustrate no more and no less than the essential aspects of an idea.

On the other hand, we found that PowerPoint stimulates the tendency to create overloaded, overly aesthetic, and overly numerous slides. With the sequentiality of a potentially unlimited number of slides that a PowerPoint document can contain, people tend to produce a multitude of slides to clarify a complex topic. We learned that especially inexperienced users tend to overload slides with content, and with elaborate formatting functions that distract from the content. Not only can a PowerPoint presentation contain an unlimited number of slides, but the file can also be copied, disseminated, and stored an unlimited number of times. These files can contain an abundance of information which is only automatically processable to a limited extent. We observed that managing an abundance of PowerPoint files became an innovation bottleneck at BITS. We call this the Scarcity and Abundance Paradox and examine it in the following sections.

Thesis T3 (Scarcity): PowerPoint's *limited functionality* and *limited space per slide* constrain the amount of conveyable information, which can lead to information scarcity

In the previous sections, we elaborated on the point that PowerPoint's captivating qualities help innovators to focus on the essence of ideas, and thereby support clarification. As we argue in the following paragraphs, taking a closer look at the limited amount of displayable information in PowerPoint is a good starting point for understanding a third paradox, namely the co-existence of information scarcity and information abundance.

As we learned in our field study, creating, externalizing, disseminating, and internalizing knowledge is an essential aspect of innovation processes at BITS. As PowerPoint plays an important role in all these practices, it is worth examining its effects from a knowledge management perspective in more detail.

To begin with, PowerPoint slides have a fixed format that is optimized to fit on a screen or a sheet of paper. Unlike other presentation tools (e.g. Prezi), PowerPoint does not allow zooming in or out on slides in presentation mode. It is possible to zoom in on a slide up to 400% in editing mode, which implies it would theoretically be possible to fit up to four times more content on a slide by using smaller fonts and objects. In practice, however, we usually do not observe such usage, because navigating on heavily loaded slides is cumbersome in PowerPoint, plus such slides would be very difficult (if not impossible) to read in presentation

mode. Not surprisingly, all PowerPoint presentations in our field study conform to the standard format, exploiting the available space in a legible manner, to varying extents. This implies that PowerPoint's capacity to convey larger amounts of complex information is limited.

In addition, the semantic representability of objects created in PowerPoint is limited and makes it difficult to capture complex relationships. Semantic mappings between concepts cannot be represented in PowerPoint at all, which creates an additional barrier to the amount of representable information:

> *"I use whatever we've got available. I map my scribbling into PowerPoint slides that will basically look like process maps. I take snapshots of those, save them as graphic files, and put them on a set of linked Confluence pages. Ideally, I would have liked to have linked the hierarchy of maps together, but image mapping is impossible."*
> [i46, technical writer, BITS]

Notwithstanding the limited range of available functionality in PowerPoint, we observed people at BITS making a virtue out of this necessity by using PowerPoint as a flexible and interactive design tool to collaborate with customers and partners. In fact, the limited (and widely known) functionality of PowerPoint reduces complexity for less technically versed users. PowerPoint allows people with different levels of technical expertise, with different degrees of specialization, and from different social worlds to collaborate on a common object. In such settings, it would be easier to use simpler, lightweight tools with limited functionality than special purpose, heavyweight tools which may give the designer greater flexibility but are not suitable in interaction with customers. As opposed to purpose-specific prototyping tools, which have a steeper learning curve for novice users, PowerPoint allows even non-expert users to create visual prototypes relatively quickly and easily. In addition, these PowerPoint-prototypes can be sent around and run everywhere where PowerPoint is installed, which also enables customers to change them easily. In a nutshell, the scarcity thesis states that using PowerPoint can lead to information scarcity through its limited functionality and ability to convey more complex information.

Antithesis AT3 (Abundance): PowerPoint's *digitality*, *integrability*, and *sequentiality* enable the potentially unlimited (re-)production, dissemination, and storage of slides, which can lead to information abundance

As we further learned from our field study, managing knowledge that is captured in various innovation-related documents is crucial to maintain an overview. Since a larger share of these documents are PowerPoint presentations, we were also eager to find out how well these can be managed at BITS. The short answer is: Not that well.

First and foremost, we observed that the sheer amount of PowerPoint presentations and slides can be overwhelming. Particularly when groups collaborate on a presentation, many participants complain about the limited control and structured support for collaborative work practices in PowerPoint. One major disadvantage is that there is no possibility to restrict create, read, update, and delete operations on PowerPoint presentations other than on the document level. Neither is there a structured version support. In practice, people who collaboratively work on PowerPoint presentations tend to work around this drawback by

creating many backup copies. As digital artifacts, PowerPoint presentations can easily be copied, shared, and stored an unlimited number of times.

In addition, PowerPoint presentations can be integrated in a number of intranet applications, for instance as online slideshows in Atlassian confluence, which is part of the intranet at BITS. This increases the number of PowerPoint presentations to a level that quickly exceeds what is tolerable:

> *"That is a horror for me. (...) If you work with PowerPoint, you will have ten copies of everything, because everybody wants it just a bit differently and everybody has a slightly different version in a slightly different location. (…) Anywhere where non-IT-people are involved, where it moves more toward business and management and sales, they just do not have structured working practices. (...) Everybody just copy-pastes everything, every single time."*
> [i42, technical consultant, BITS]

In the second year of our field study, BITS introduced a groupware solution based on SharePoint in response to our study's findings about the employees' growing need to collaborate on documents such as PowerPoint:

> *"We were doing a team presentation and we each had our own little section in a set of slides, and just trying to manage that was such a hassle. We were all sending our updates to each other, merge them and (so on). I would say a collaborative Google docs system or SharePoint would have been ideal for that."*
> [i46, technical writer, BITS]

While it would technically be possible to use office web applications like SharePoint or Google docs, a number of barriers hinder BITS from fully overcoming the PowerPoint abundance. Apart from the not to be underestimated technical complexity of configuring a SharePoint solution, legal obligations prevent the company from storing just any kind of document on cloud servers. After all, many BITS employees deal with security sensitive customer information and are legally obliged to conform to restrictive banking security laws. We therefore do not expect that the problem of PowerPoint abundance can in the long run be fully solved at companies like BITS.

Another challenge with capturing much innovation-related knowledge in many PowerPoint presentations is that there is no possibility of algorithmically searching and prioritizing PowerPoint files with respect to their importance. Unlike websites that can be connected with hyperlinks, which enables algorithms like PageRank to search and sort content according to their relevance for a specific search term, PowerPoint does not have the functionality to semantically link objects, slides, or presentations.

In addition to the abundance on the document level, we found that the slides themselves are also often overloaded. The exaggerated detail on many PowerPoint slides was a popular subject to mockery in our field study:

> "*I've never seen a company where the slides have so many details. Obviously, if you understand that slide you understand it all, but sometimes PowerPoint just goes too far."*
> [i47, product manager, BITS]

For many participants, it is a challenge to satisfy the information needs of various stakeholders on the one hand, and not provide too much information on the other hand. It seems to be difficult to create and maintain slide sets that are equally well understood by different stakeholders, such as developers, requirements engineers, user experience designers, and managers. This seems to go hand in hand with a tendency to overload slides with content.

Novice users are particularly fond of overloading slides, exaggerating the amount of decorations and animations that distract from the essential content. Interestingly, technical people often seemed to be aware that they tend to overstep the expected level of detail:

> *"They tend to use these PowerPoint slides with masses of bricks in the wall, and each one has little labels, and it means absolutely nothing. (...) It is not clear, it is not helpful. It really blinds you. (...) You cannot see the wood for the trees. It is just too much. (…) I find myself doing exactly the same thing, (…) giving them too much information. (…) I know it is a temptation, especially for technical people, to explain everything they understand. You get carried away."*
> [i53, software engineer, BITS]

In a nutshell, the abundance thesis states that PowerPoint's digitality, integrability, and sequentiality tempt users to produce, store, and disseminate an overwhelming number of PowerPoint presentations that are difficult to manage. It is difficult to find information in this abundance of PowerPoint documents because search engines cannot semantically process the content. This poses a real challenge for knowledge management at BITS.

6 Synthesis and Extension

In the previous section, we discussed three PowerPoint paradoxes from the empirical insights obtained in a qualitative field study of innovation practices at a software firm. Next, we provide a dialectic synthesis of the three paradoxes through which we provide an explicit answer to the guiding research question of this paper*: How do digital artifacts enable and constrain innovation practices?* We then demonstrate the transferability of our results to other kinds of digital innovation artifacts via a comparative analysis with modeling tools and discuss implications for theory and practice.

6.1 Dialectic synthesis of PowerPoint paradoxes

In accordance with Schad et al.'s (2016) definition of paradox, we have identified three paradoxes by juxtaposing two persistently contradictory yet interdependent elements. In line with Poole and Van de Ven’s (1989) proposition that coping mechanisms may be developed via strategies that include acceptance, temporal and spatial separation as well as synthesis, we synthesize and resolve the three paradoxes below. This dialectic synthesis provides the foundation of our substantive theory. Table 3 provides an overview of the dialectic synthesis.

Table 3 – Dialectic synthesis of PowerPoint paradoxes in innovation practices			
Paradox (P)	**Thesis (T)**	**Antithesis (AT)**	**Synthesis (S)**
P1: Freedom and Captivity	T1: PowerPoint's *malleability* enables developing and expressing creative ideas freely.	AT1: The PowerPoint template, its lack of semantic representability, and social pressure around its usage constrain creative interaction.	S1: PowerPoint enables individual freedom in early innovation process phases and holds teams captive later.
P2: Clarity and Ambiguity	T2: PowerPoint's *modularity* and *sequentiality* enable users to structure thoughts, simplify complex issues, and break down large topic blocks into smaller ones, thereby allowing for a clarification of ideas.	AT2: PowerPoint enables the creation of *semantically ambiguous* and *interpretatively flexible* slides, which can lead to an ambiguation of ideas.	S2: PowerPoint enables clarification during the production of slides, but also enables ambiguation during the consumption of slides.
P3: Scarcity and Abundance	T3: PowerPoint's *limited functionality* and *limited space per slide* constrain the amount of conveyable information, which can lead to information scarcity.	AT3: PowerPoint's *digitality*, *integrability*, and *sequentiality* enable the potentially unlimited (re-)production, dissemination, and storage of slides, which can lead to information abundance.	S3: PowerPoint enables scarcity of high-quality information on the slide level but enables abundance of low-quality information on the slide deck level.

Synthesis S1: PowerPoint enables individual freedom in early innovation process phases and holds teams captive later

The first paradox is the *Freedom and Captivity* afforded by PowerPoint's malleability and related social pressures. It is important to note that PowerPoint's Freedom and Captivity can be beneficial as well as detrimental for innovation. Freedom of creative expression is a basic prerequisite for being innovative, particularly in the divergent phases of idea generation, where blue sky thinking and broadening the possible solution space are important (Brown,

2009). PowerPoint initially functions as a flexible instrument for the creative individual. Unrestricted freedom is however not always conducive to the innovation process, because at some point the number of generated ideas may exceed the available resources for developing them.

At this point, it seems desirable to narrow down the possible solution space and start a convergent phase in which decisions about ways to continue are important (cf. Dennis et al., 2008). Here, PowerPoint functions as a mediating communication device between different stakeholders, and its constraining qualities can help people to focus on the essence of an idea. When using PowerPoint for this purpose, users should be aware of the inherent danger of distancing themselves too much from the idea and the intended audience. Instead of structuring discussions along PowerPoint slides, the slides should be seen as an anchor to which people can return when a visual representation of the disputed issues is necessary.

As a coping strategy to deal with this first paradox, temporal separation shows that people experience the Freedom and Captivity of PowerPoint at different points in time. In early, divergent phases of the innovation process that require idea generation, PowerPoint lets users express creative ideas freely through its malleability. But this freedom is never unrestricted. As Yates and Orlikowski (2007) point out, enablement and constraint cannot be considered as separate aspects, but rather as two sides of the same coin. In the same way a freeway can give drivers the impression of a free voyage, while forcing them to stay on the paved road, PowerPoint's freeing and captivating qualities cannot be separated. Especially in later, convergent phases of the innovation process that require idea selection and elaboration, PowerPoint shows its constraints. Without the possibility of semantic representation, the objects created in PowerPoint cannot be reused outside the program. Social pressure also forces people to use PowerPoint in certain settings and in specific ways.

A spatial separation of this paradox shows that people tend to experience more of PowerPoint's freeing qualities in individual settings (e.g. while editing slides for themselves), whereas all stakeholders tend to experience more of PowerPoint's captivating qualities in interpersonal settings (e.g. while presenting slides or collaboratively editing them). In our field study, people escaped from this captivity by complementing the strengths of PowerPoint with those of other tools, such as using whiteboards in workshops, dedicated software modelling, or prototyping tools to professionalize the objects created in PowerPoint. We found that this exchange could be strengthened by providing better possibilities for structured import and export.

The distinctive malleability, modularity, and sequentiality of PowerPoint seem to fit the emergent nature of innovation practices, as people tend to prefer general tools over specialized ones, particularly when communicating with various stakeholders in different roles (Carlile, 2002; Cherubini et al., 2007). Contrary to many specialized tools, PowerPoint provides greater freedom of expression and facilitates the seamless transition between representing an idea on a slide and the envisaged idea, for instance when people use PowerPoint to combine prototyping with user interface mock-ups. PowerPoint does not prescribe narrow syntactics or semantics and users can express themselves freely, constrained only by the available space per slide, the template, and the lack of semantic representability. The latter has dire consequences for innovation practices in software firms,

as it does not satisfy the requirements for the structured, formal, and automatable working practices of software engineers.

We have observed that PowerPoint usage can run up against its limits and result in negative outcomes for innovators. The routinized use of PowerPoint might constrain more creative practices, such as freehand drawing or simply talking to one another. This can be particularly detrimental when using PowerPoint to brainstorm ideas at an early phase in the innovation process. The forced linearity and sequentiality of a PowerPoint presentation constrain free thinking, creative discussions, and improvisations (cf. Gabriel, 2008), increase the distance between speaker and audience, lead to a tendency to defer questions to the end, and reduce the speaker's responsiveness to the audience (cf. Yates and Orlikowski, 2007).

Synthesis S2: PowerPoint enables clarification during the production of slides, but also enables ambiguation during the consumption of slides

The second paradox consists of the *Clarity and Ambiguity* afforded by PowerPoint's modularity, sequentiality, and flexibility. Analogous to its freeing and captivating qualities, PowerPoint's clarifying and ambiguating functionalities constitute two persistently contradictory yet interdependent elements creating a paradox. Contrary to the coping strategy we identified in the previous paradox – temporal and spatial separation – we observed that innovators apply a different coping strategy to the Clarity and Ambiguity paradox. A temporal and spatial separation is possible but would not resolve this paradox satisfactorily. Instead, innovators at BITS respond to this paradox with acceptance, by embracing its tension and appreciating their differences (Poole and Van de Ven, 1989).

It is again important to note that PowerPoint's clarifying and ambiguating qualities have beneficial as well as detrimental effects on innovation practices. Clarifying the essence of an idea is crucial for making decisions on which direction to take in the innovation process, but oversimplification can backfire when it leads to overestimating the idea's maturity and underestimating the necessary completion effort. PowerPoint's sequentiality and modularity enable users to structure their thoughts and focus on essential aspects, but they should be frank and honest about the limitations and avoid overselling. Ambiguation is undesirable for innovation in many instances, as misinterpretations induce flawed decisions and cripple collaboration. However, embracing flexible interpretations can trigger valuable input from stakeholders with different viewpoints, and help to identify tension that was previously not considered. Here, the semantic ambiguity and flexibility of content created in PowerPoint limit the degree of achievable clarity.

A temporal and spatial separation of this paradox would reveal that different people perceive PowerPoint's clarifying and ambiguating qualities to varying extents in different settings at different points in time. For instance, individual PowerPoint users promote their own sense-making process when producing slides, clarifying essential aspects for themselves. This also works for small groups who accommodate their conflicting views by collectively producing clarifying PowerPoint slides in workshops. However, this should not be the final step, as those who later consume these slides without having participated in their production will quite likely be exposed to misinterpretation. It can help to write down important aspects in a proper text document, but there is no guarantee that this will convey the message

unambiguously to all stakeholders either, as it depends on the communication skills of the sender and the cognitive capacity of the receivers.

PowerPoint approaches the status of a universal business language as its usage expands to ever more practices, such as documentation, software modeling, or prototyping (Buckl et al., 2015; Gabriel, 2008; Schoeneborn, 2013). Innovators may benefit from network economics in this regard, as they may reach a variety of stakeholders with different backgrounds (Yoo et al., 2010) via PowerPoint, which is pre-installed and easy and ready to use on every computer. Due to the digital nature of PowerPoint, slides can be shared with others without many intermediate steps, and through various digital channels, for example chat, email or wiki.

PowerPoint also plays a central role in negotiating with relevant stakeholders because innovators can use the tool to persuasively display information that does not yet exist. PowerPoint slides are therefore often a decisive catalyst in mobilizing ideas (cf. Kaplan, 2011; Stark and Paravel, 2008). But that same persuasiveness can backfire when the audience overestimates the idea's degree of completion. The phrase *paper does not blush*, meaning that one can write everything on paper whether it is true or not, also applies to PowerPoint, which allows users to visualize ideas, models, and prototypes regardless of whether they are true or technically accurate. The expected format of a PowerPoint presentation is often a sales pitch, so presenters tend to signal a preparedness that overshadows the idea's degree of maturity. Ambiguities and misunderstandings may therefore arise when PowerPoint presentations do not provide sufficiently accurate information on the content, especially when the author is not present.

The ongoing expansion of PowerPoint's usage contexts may also cause misinterpretations that result from diverging expectations (Yates and Orlikowski, 2007). For instance, PowerPoint documents that serve the dual purpose of presentations and project reports often miss the information requirements of either (Schoeneborn, 2013). Although PowerPoint documents are not intended to be used in isolation, but rather accompanied by oral explanation, we have observed that PowerPoint slides are often a medium for software documentation (cf. Schoeneborn, 2013). Similarly, our analysis of PowerPoint usage for modeling and prototyping shows that the same usage pattern can be successful in one context, but a failure in another.

Synthesis S3: PowerPoint enables scarcity of high-quality information on the slide level, but also enables abundance of low-quality information on the slide deck level

The third paradox is the *Scarcity and Abundance* afforded by PowerPoint's digitality, integrability, and sequentiality. We have observed instances where PowerPoint enables information scarcity, and instances where PowerPoint enables information abundance. These contradictory yet interdependent elements exist simultaneously and persist over time, which again creates a paradox (Schad et al., 2016).

A spatial separation (Poole and Van de Ven, 1989) of the Scarcity and Abundance paradox shows that Scarcity and Abundance are interdependent and coexist on different levels of PowerPoint. Quite ironically, it is the scarcity of representable high-quality information on the

level of a PowerPoint slide that induces the abundance of low-quality information on the presentation level. Because the representability of available information is limited on each slide, people tend to need many slides to support a complex argument, leading to a fragmentation of coherent content. This has detrimental effects on managing innovation-related knowledge. It remains a challenge for organizations like BITS to systematically create, externalize, disseminate, and internalize knowledge. In our field study, the extensive use of PowerPoint in these practices generated more problems than it solved. PowerPoint presentations have major constraints as a knowledge repository, because without semantic representation, relevant PowerPoint documents are hard to search and categorize. Even if someone is lucky enough to find the desired presentation, the context is often missing.

As our study shows, innovators often turn a necessity into a virtue by using PowerPoint's limited functionality and limited amount of displayable information to structure thoughts and focus on the essence of an idea. Existing studies see this mainly as a disadvantage, and several scholars have criticized PowerPoint usage for causing information scarcity. For instance, the data visualization expert Edward Tufte has noted that even simple statistical facts are cumbersome to display on PowerPoint slides, because the fixed format and limited space per slide would ambiguate the representation of data that could otherwise be displayed clearly in a table in a text document (Tufte, 2003).

Similarly, human-computer interaction expert Clifford Nass has argued that PowerPoint tempts users to focus only on outcomes, but not on the process of creating knowledge, which is why more complex arguments would be impossible to force into the fragmented, sequential, linear, and rectangular limited slides (Parker, 2001). While our data confirms these negative effects of PowerPoint-induced information scarcity, it also shows positive effects, such as stronger focus and simplicity of use, which can lead to the simplification of complex issues.

Whereas some prior studies mention in passing an abundance of PowerPoint documents in organizations (Kaplan, 2011; Schoeneborn, 2013), our findings offer new insights on what happens in large organizations that face the challenge of managing an abundance of unstructured but important knowledge captured in PowerPoint.

6.2 Extending the Scope of PowerPoint Paradoxes to Other Digital Innovation Artifacts

From our dialectic synthesis of PowerPoint paradoxes, we have learned that digital innovation artifacts cannot simply be characterized as either beneficial or detrimental for innovation. Next, by means of a comparative analysis, we show that our substantive theory of PowerPoint paradoxes can be meaningfully applied to other kinds of digital innovation artifacts.

To maximize the transferability of our substantive theory, we focus our comparative analysis on a digital innovation artifact with characteristics that seem to be quite different from PowerPoint, namely modeling tools. These are software that facilitates the structured creation of software models according to a well-defined notation, such as UML or BPMN.

Many modeling tools, such as Enterprise Architect, Visio, Visual Paradigm, or Signavio, offer the semantic representation of created models, allowing automated generation and actualization of code according to changes in the model. Many computer science, software engineering, and information systems programmes at universities around the world uphold the pure doctrine that software designers should use modeling tools, despite contrary empirical evidence indicating that they prefer to do otherwise in practice (e.g. Cherubini et al., 2007; Ossher et al., 2010; Sandkuhl et al., 2018, and this paper). We argue in the following subsections that the paradoxical tension in PowerPoint can also be found in modeling tools.

Paradox P1: Freedom and Captivity in modeling tools

Compared to PowerPoint, modeling tools are less malleable in that they enforce narrower usage patterns. Structured modeling is only possible according to the narrowly defined semantics of a standardized modeling notation.

The advantages of the enforced compliance with metamodels are semantic representability and support. Most professional modeling tools offer a wide range of comprehensive templates with basic shapes and forms that allow the creation of extensive models. The semantically enriched models can easily and conveniently be stored, shared, versioned, and linked to other artifacts (Bellamy et al., 2011; Ossher et al., 2010). Consistency management is an automated task, therefore a single consistent change in style or terminology of an element is automatically transferred throughout many models (Ossher et al., 2010). The semantic representation of entity relationships also enables the automated generation and continuous updating of software code according to the most recent version of the model. This liberates users from many manual and cumbersome tasks and allows them to focus on the more creative process of generating, developing, and communicating software design ideas, within the constraints of the modeling language and tool. In short, like PowerPoint, modeling tools let users express creative ideas freely, although they permit less freedom than PowerPoint due to lower malleability (cf. T1).

The disadvantage of the constraints imposed by metamodels is that modeling tools have narrower applicability and are harder to learn, as they force users to follow a predefined order of development. The latter causes premature commitment by imposing inappropriate levels of detail and order (Ossher et al., 2010). This is especially detrimental when the modeling tool distracts from the core sketching experience and interrupts users in their natural creative flow, preventing meaning to evolve as content is created (Bellamy et al., 2011). Even modeling tools that support some of the most widespread modeling languages, such as UML and BPMN, have been criticized for their lack of intuitiveness, frequent interruptions of the creative flow, not being commonly understood among non-technical stakeholders, and constraining creative interactions due to a lack of simultaneous collaboration possibilities (cf. Wüest et al., 2015). In addition, many modeling tools only allow models to be saved in a proprietary file format, creating lock-in effects and holding users captive in one tool. In short, like PowerPoint, modeling tools hold people captive and constrain creative interaction, and they cause captivity to a higher extent than PowerPoint due to enforced metamodels (cf. AT1).

In conclusion, the paradoxical tension between Freedom and Captivity also applies to modeling tools. Similar to PowerPoint, modeling tools enable individual freedom in early innovation process phases (though somewhat less) and hold teams captive later (though somewhat more). The coping strategy described in Synthesis 1 may also be usefully applied in the context of modeling tools.

Paradox P2: Clarity and Ambiguity in modeling tools

Compared to PowerPoint, modeling tools offer similar degrees of modularity in that the created models and their parts can easily be cut out, copied, pasted, and grouped in the same modeling tool. Since the semantic representability of models makes it easier to add single consistent changes and integrate them into other software development tools, modeling tools allow a more flexible rearrangement of models outside the forced sequentiality of PowerPoint (Ossher et al., 2010). Because all models in one notation comply with the same metamodel, modeling tools permit the structural and behavioral aspects of software systems to be described more clearly than PowerPoint, and inconsistencies are less likely to occur between models or between parts of a model. Modeling tools also permit navigating complexity through graphical refinement (e.g. expanding high-level processes to show lower-level sub-processes) and aggregation (e.g. collapsing higher-level processes to hide lower-level sub-processes). In short, like PowerPoint, modeling tools provide a structured way to simplify complex issues and break down large topic blocks into smaller ones, thereby allowing for idea clarification (cf. T2).

Our data shows that even skillfully crafted software models are rarely unambiguous in the lived experience of software design, particularly in communication with customers and business-oriented stakeholders. Prior studies have shown that many of the most common modeling languages, such as UML and BPMN, are semi-formal, graphical, general-purpose modeling languages that allow the expression of model components in natural language, which is inherently ambiguous (Kamsties and Paech, 2000). Contrary to formally specified mathematical or computational models, such as petri nets or finite-state machines, which are not universally used in software development, the created models in UML and BPMN allow multiple interpretations.

Several authors have argued that one of the most problematic aspects of UML is ambiguity resulting from a number of overlapping and weakly defined constructs. For instance, Grossman et al. (2005) show that most software developers think that UML is so insufficiently specified that it allows for misinterpretation, that there are so many different UML diagrams and notational systems that it is hard to understand which one to use in a given situation, and that UML diagrams are represented in so many different places and in so many forms that it is hard to know how to use them effectively.

Closely related to this, Dijkman et al. (2007) show that it is difficult to provide formal semantics in BPMN due to ambiguities and complexities resulting from its graphical constructs and inconsistent terminology. In the light of these shortcomings of modeling tools, it is not surprising that even software developers often use PowerPoint for modeling purposes. In short, like PowerPoint, modeling tools, similarly to PowerPoint, enable the creation of semantically ambiguous and interpretatively flexible models, which can lead to idea ambiguation (cf. AT2).

In conclusion, the paradoxical tension between Clarity and Ambiguity also applies to modeling tools. Similar to PowerPoint, modeling tools enable individual clarification in the production of models (though somewhat more than PowerPoint) and foster interpersonal ambiguation during the consumption of models (though somewhat less than PowerPoint). The coping strategy described in Synthesis 2 may also be usefully applied in the context of modeling tools.

Paradox P3: Scarcity and Abundance in modeling tools

Compared to PowerPoint, modeling tools offer more comprehensive, purpose-specific functionality for modeling and allow the creation of more extensive models than those that would fit on the limited space of PowerPoint slides. However, modeling tools usually lack the general-purpose functionalities of PowerPoint, such as freeform and metamodel-agnostic modeling. This limits the conveyable information to what is possible to express according to the predefined metamodel. Similar to slides created in PowerPoint, models created in modeling tools are only useful for communicative purposes if they can be clearly illustrated on surfaces of overseeable size, such as a sheet of paper, a computer screen, or a projected screen (Becker et al., 2000). After all, any model in software design is by definition and by necessity a reduction of the reality, embodied in the socio-technical system that the model is aimed to describe or envision. In short, like PowerPoint, modeling tools constrain the amount of conveyable information, which can lead to information scarcity (cf. T3).

However, similar to PowerPoint, the digitality, integrability, and limitless refinement possibilities modeling tools offer also allow information abundance by enabling the potentially unlimited (re-)production, dissemination, and storage of models (cf. AT3).

In conclusion, the paradoxical tension between Scarcity and Abundance also applies to modeling tools. Similar to PowerPoint, modeling tools enable scarcity of high-quality information on the level of individual models but abundance of low-quality information on the level of collections of models. The coping strategy described in Synthesis 3 may also be usefully applied in the context of modeling tools.

7 Discussion

7.1 Theoretical implications

This paper develops a substantive theory of the paradoxes of digital innovation artifacts via an in-depth analysis of PowerPoint usage in the innovation practices of a software firm. Our data shows that PowerPoint enables and constrains a variety of practices that go beyond the software's intended purpose of editing and presenting slides. We had the unique opportunity to obtain in-depth access to the interpretations of people that are directly immersed with the phenomenon in practice. We seized this opportunity to critically reflect and dialectically synthesize the often ambivalent and sometimes contradictory perceptions of people who use the tool. In addition, we show via a comparative analysis with modeling tools that our substantive theory can be extended to other kinds of digital innovation artifacts, which

answers the guiding research question: *How do digital artifacts enable and constrain innovation practices?*

Table 4 – Substantive theory of the paradoxes of digital innovation artifacts		
	Stability and control	**Flexibility and change**
Paradox 1	**Captivity:** Digital innovation artifacts constrain creative interaction.	**Freedom:** Digital innovation artifacts enable developing and expressing creative ideas freely.
Paradox 2	**Clarity:** Digital innovation artifacts enable users to structure thoughts, simplify complex issues, and break down large topic blocks into smaller ones, thereby allowing for a clarification of ideas.	**Ambiguity:** Digital innovation artifacts enable the creation of semantically ambiguous and interpretatively flexible content, which can lead to an ambiguation of ideas.
Paradox 3	**Scarcity:** Digital innovation artifacts constrain the amount of conveyable information, which can lead to information scarcity	**Abundance:** Digital innovation artifacts enable the potentially unlimited (re-)production, dissemination, and storage of slides, which can lead to information abundance.

Table 4 illustrates the core of our substantive theory – three paradoxes that each constitute two persistently contradictory yet interdependent elements (Schad et al., 2016). The first paradox juxtaposes the provided Freedom and Captivity of digital innovation artifacts. The second paradox dialectically examines clarifying and ambiguating effects. The third paradox capitalizes on the parallel facilitation of information scarcity and information abundance enabled by digital innovation artifacts. By dialectically synthesizing the three paradoxes, we follow what Poole and Van de Ven (1989) term a coping strategy that involves temporal or spatial separation, and acceptance. This allows us to dissolve and reconcile the paradoxical effects of digital artifacts (Ford and Backoff, 1988)

The two underlying opposing poles find their roots in the ongoing discourse about flexibility and change versus stability and control of information systems (cf. Ciborra et al. 2000). What we add to this discourse is that we should not try to simplify the reality into polarized ‘either/or’ distinctions but should reconcile the ‘and’ conjunction by appreciating the complex interrelationships between the opposing poles (Tilson et al., 2010) and embracing the duality of paradoxes (Farjoun, 2010). From this perspective, our study contributes rich insights about the nature of the paradoxes of digital innovation artifacts and how they can be meaningfully and creatively reconciled in practice.

From our dialectic synthesis of PowerPoint's paradoxical effects on innovation practices and our comparative analysis with modeling tools, we hypothesize that any technology that offers similar kinds of affordances could have similar paradoxical effects on innovation practices. It follows that a digital innovation artifact cannot be judged simply against its affordances. Instead, using digital innovation artifacts generates a distinctive tension that requires a critical dialectic synthesis to describe the paradoxical effects and identify appropriate coping strategies. We suggest that a single digital artifact should not be seen as a static part of an organization, but as an integral part of innovation practices that is enacted in a larger ecosystem of digital innovation artifacts.

Yates and Orlikowski (2007) pointed out that enablement and constraint of digital technologies cannot be considered as alternatives (a dualism), but rather as two sides of the same coin (a duality). From this perspective, the paradoxes developed here reflect the role of enablement and constraint in that they emphasize the ambivalences of the enabling and constraining effects of digital artifacts on innovation practices. In fact, our contribution goes a step further by illustrating how digital innovation artifacts can sustain a chain of practices that may ultimately appear as not only ambivalent, but *contradictory*.

This has important implications for the study of affordances. Many existing studies use the concept of affordances as a way to get things done in a fairly straightforward way. There are various opinions about affordances, but the general idea is that they enable and constrain action. In this case, they enable and constrain innovation practices. Our study shows that a digital artifact can offer an array of affordances that, taken together, have paradoxical effects on innovation practices. Like organizational paradoxes, which require managers to accept and embrace rather than try to resist contradictions (Hargrave and Van de Ven, 2017), digital artifact paradoxes require users to develop paradoxical thinking in order to cope with and work through contradictions and initiate virtuous cycles of acceptance and synergy. Either way, the connection between the affordances of digital artifacts and their effect is not as straightforward as it often seems to be in the existing literature. Instead, it can be paradoxical. It would be a missed opportunity to overlook or oversimplify these paradoxical tensions, as they can be a source of productive and creative digital artifact usage. We hope that our study inspires and guides further research on the paradoxical effects of digital artifacts on various practices.

7.2 Practical implications

Digital artifacts support innovators throughout the innovation process. For instance, they enable specifying representations of envisaged new software products. They let users create concrete manifestations of abstract ideas or concepts that can be collaboratively shared among teams. Due to their emergent, unfinished, and partial nature, digital innovation artifacts facilitate communication and collaboration. In this vein, our study has practical implications for innovating software firms in that it illustrates the tradeoffs of using digital innovation artifacts and creates awareness of the challenges and opportunities.

Our contribution helps individuals and organizations that experience paradoxes of digital innovation artifacts to recognize them and embrace them constructively. This includes being aware of the different settings and points in time where the opposing poles of the paradoxes occur. While using digital innovation artifacts brings certain benefits, it also comes at a cost.

Through their paradoxical effects, digital innovation artifacts support innovation practices, such as generating ideas, modeling innovative software, persuading decision-makers, or prototyping. But the extensive use of digital innovation artifacts also generates problems, such as constrained creativity, misinterpretation, and poorly manageable knowledge.

Our study provides explanations of why practitioners refuse to use the many available specialized software tools, despite their apparent advantages. From a cost-benefit viewpoint, one should critically question the practical value of (often expensive) purpose-specific tools for prototyping and software modeling that are less frequently used than general-purpose tools.

When it comes to PowerPoint, one should be aware that the tool has reached a level of acceptance that resembles social coercion, because a PowerPoint presentation is the expected format in many organizational settings. After years of extensive appropriation and entanglement in everyday work practices, PowerPoint is strongly anchored in people's consciousness, resulting in its extensive use as a communication medium in many situations. Prescribing firm-wide guidelines on which tools to use and which formal semantics to follow will quite likely foster resistance, as people feel constrained in their freedom. But without clear guidelines, consistent usage is difficult, if not impossible. An approach that allows people to freely express ideas in the tools they prefer, while simultaneously ensuring consistent usage, would be necessary.

Better support to semantically link content and objects in the tools people use, such as PowerPoint, would be a promising improvement. More recent technological developments like web-based collaboration tools (e.g. wiki, Google docs, or SharePoint) may be a step in the direction of improving versioning and searchability, but it is reasonable to assume that people will continue to use PowerPoint outside these web-based environments. A PowerPoint presentation can serve as a working document that can be sent via email for feedback. This way, the sender has a relatively high level of control over how many people can access and edit it. In contrast, a web-based collaboration tool is more open, and documents are accessible to many people, with authors having limited control over who can access and edit them. Further research should explore the potential of extending PowerPoint functionality with automatic metadata generation and file format conversion (cf. Ossher et al., 2010).

7.3 Limitations

As the goal of this study was to understand how digital artifacts enable and constrain innovation practices, we chose qualitative methods and inductive theory building to identify and describe the phenomenon. Our study focuses on one software firm and one tool to limit complexity and describe the phenomenon in depth. To the best of our knowledge, no prior study has yet provided a comprehensive analysis of how different kinds of digital innovation artifacts enable and constrain innovation practices. Our in-depth analysis of PowerPoint usage should therefore be seen as only a starting point in a series of further studies that examine the paradoxical effects of various digital artifacts on innovation practices in organizations. It could be interesting to study in detail the effects of other artifacts, such as digital drawing tools or social software. Our extension of PowerPoint paradoxes to modeling tools provides an example of how such follow-up studies could look like.

This paper explores innovation practices at a software firm that may be arguably innovative, but not necessarily leading edge. Whereas these insights offer possibilities to understand the effects of digital artifacts on innovation practices, they do not offer comprehensive guidelines and clues about how to *ideally* support these practices. Further behavioral field studies may examine how leading-edge companies innovate with digital artifacts to provide structured guidance and best practices. Further design-oriented studies may also design, develop, and evaluate innovative digital artifacts in order to solve some of the challenges identified here.

8 Conclusions

In this paper, we explore how digital innovation artifacts enable and constrain innovation practices. Through a qualitative field study at an innovating software firm, we show that PowerPoint, as a dominant digital innovation artifact, offers an array of affordances that, taken together, can have paradoxical effects. In line with Schad et al.'s (2016) definition of paradox, we identify three persistently contradictory yet interdependent ambivalences – namely Freedom and Captivity, Clarity and Ambiguity, and Scarcity and Abundance. By means of dialectic synthesis, and in accordance with Poole and Van de Ven's (1989) propositions, we identify appropriate coping strategies that include acceptance, temporal separation, and spatial separation. Via a comparative analysis with modeling tools we demonstrate the transferability of the three paradoxes to different kinds of artifacts and suggest a substantive theory of the paradoxes of digital innovation artifacts.

Our substantive theory offers rich insight into the complex interrelationships between digital artifacts and their effects on the underlying practices. We hypothesize that any digital artifact with similar affordances can have similar paradoxical effects that need to be embraced and reconciled, rather than regarded in isolation. Our study shows how a careful examination of such mundane digital artifacts like PowerPoint can reveal complex, multifaceted, and contradictory tension. This provides a practical example of how an in-depth analysis of artifact usage can deepen our understanding of the underlying practices (cf. Riemer and Johnston, 2014).

Our substantive theory offers fruitful suggestions for design researchers. When designing support for innovation practices, one needs to bear in mind the paradoxical role of digital innovation artifacts. We suggest that combining the semantic representability of specialized tools with the malleability general tools would better fit the structured yet flexible innovation practices of software developers.

Part of our contribution is to condense our rich insights in a way that makes them transferable to a broader class of companies that share basic assumptions with the software firm we studied. These could include software firms that encourage employees to innovate and engage in interdisciplinary IS development, as well as industrial manufacturers, telecommunication corporations, consulting firms or financial service providers, which today may also have large software development branches.

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