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Research Article

Grounded Design – a praxeological IS research perspective

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Abstract

In this paper, we propose *Grounded Design* – a particular design research (DR) approach rooted in a practice-theoretical tradition. It assesses the quality of information technology (IT) design through evaluation of emerging changes in social practices, which result from the appropriation and use of IT artifacts. The paper starts with a systematic analysis of the reasons for persistent limitations of traditional information systems DR, specifically in coping with problems of contingency and self-referentiality. Following this critique, the principles of Grounded Design are presented. Grounded Design is applied in case studies where we reconstruct the social practices observed before and during the design and appropriation of innovative IT artifacts. We call these context-specific research endeavors 'design case studies.' In conducting these case studies, Grounded Design builds upon well-established research methods such as ethnographical field studies, participatory design and action research. To support the transferability of its situated findings, Grounded Design suggests documenting increasing numbers of design case studies to create an extended, comparative knowledge base. Comparing cases allows for the emergence of bottom-up concepts dealing with the design and appropriation of innovative IT artifacts in social practice.
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Introduction

Organizing is an endeavor to enable cooperation and coordinated collective action. Technical artifacts play a major role in creating, maintaining and facilitating coordinated action in order to achieve specified objectives. Understanding exactly how technical artifacts are created and used within organizations is, of course, a central aspect of the information systems (IS) research discipline. While tools and techniques may be intended to support social practices, their purposively shaped functions nevertheless need to be adopted and activated by organizational actors to become effective in practice. We start, then, from the view that technical artifacts have a two-sided character in their nature: They consist, on the one hand, of technical, that is artificial, formal schemes or materialized functions. These are subject to deliberate design policy in accordance with functional specifications. At the same time, they need to be socially appropriated for effective and meaningful use in organizational practices (Reckwitz, 2002; Orlikowski, 2009; Kuutti and Bannon, 2014).

In creating interactive computing artifacts, information technology (IT) in principle offers a generally applicable enabling technology for coordination and organization. The design and use of IT artifacts for organizing collective action thus constitute IS as *sociotechnical systems,* the social practices of which are structured and performed through appropriating and making sense of formal organizational prescriptions on the one hand and IT system functions on the other. Designing IT artifacts for, and putting them to effective, use therefore, constitutes a massive intervention into the established social practices of an organization. Organizations thus serve as 'laboratories for IS research,' where the development and use of artifacts can be studied in the context of an organization's social practices (Braa and Vidgen, 1999).

IS research, and in particular IS design research (DR), then, exists to study these interrelationships and to provide scientific 'knowledge that aids in the productive application of IT to human organizations and their management' (ISR, 2002).

The discipline's general request of designing and implementing IS 'within an organization for the purpose of improving the effectiveness and efficiency of that organization' (Hevner *et al.*, 2004) has produced different research traditions and theoretical perspectives.

One such perspective is that of the design-centered approach, which forms a newly emerging mainstream in IS research, focusing on IT artifacts that presumably enable actors to improve an organization's performance. They presuppose the existence of sufficient functional requirements to this end and are based on the expectation that these requirements can be reliably determined beforehand, either by the organization itself or by interacting with designers (Walls *et al.*, 1992; Kuechler and Vaishnavi, 2012). Designing IS artifacts however, in our view, comprises only a part of IT development problems. The 'design centered' perspective, we suggest, systematically ignores the self-referential nature of organizational change and in particular of IT development, according to which appropriating an IT artifact for use changes the very social practices for which the artifact had originally been designed (Wulf, 1999; Brödner, 2009; Pipek and Wulf, 2009). This inevitably leads to frequent changes of the requirements demanded during the process of design and implementation. Critics have suggested that this dynamic character is insufficiently reflected in IS design, research having paid little attention to the way that artifacts 'mould' the organizational context (e.g. Dahlbom and Mathiassen, 1993; Orlikowski, 2000; Dittrich *et al.*, 2002).

A second basic research perspective can, in contrast, be characterized as socio-centric, as it focuses on the processes of how humans interact with, make sense of and appropriate an IT system's functions in the context of an organization's social practices. While this approach considers the IT artifact as exogenously structured, it attempts to explain how the system's functions are adopted and activated for effective use in the organizational context and how, consequently, different social practices emerge. Critics equally argue that this widespread research tradition ignores the material dimension of social practices in organizations (Engeström and Blackler, 2005; Orlikowski, 2007, 2009; Orlikowski and Scott, 2008; Doolin and McLeod, 2012), arguing that we are 'desperately seeking the "IT" in IT research' and suggesting a need for 'theorizing the IT artifact' (Orlikowski and Iacono, 2001).

As a result of the apparent contradictions inherent in contrasting perspectives, IS has recently been elaborating on its disciplinary identity and practical relevance by debating the core issues to be investigated and the theoretical perspectives that need to be adopted (Hirschheim and Klein, 2003; King and Lyytinen, 2006). However, the causes of the main problems in IS development and unexpectedly poor IS performance have rarely been reflected upon. Insufficient research on the realities of failed IS practices, over-emphasis on theorizing, particularly in the form of IS design theory with questionable use value, and inadequate epistemological foundations, we suspect, are among the salient reasons for this 'poverty.' Empirical work indicating insufficient or absent productivity gains as well as considerable numbers of failing IT development projects reveal time and again that expectations about improved organizational performance are regularly frustrated (Dedrick *et al.*, 2003; Brödner, 2009). Alarming numbers of IT application projects 'fail to deliver key benefits on time and to target cost and specification. This can be ascribed to general absence of collective professionalism in the IT industry, as well as inadequacies in the education and training of customer and supplier staff at all levels' (Royal Academy of Engineering, 2004: 4).

These problems raise, among other things, basic questions about the relationship between science and design and between theory and practice. Progress, we believe, requires a fundamental reconceptualization of the foundational epistemologies IS research, since persistent failures may indicate poor understanding of their origin. The paper aims to systematically disclose the reasons for persistent difficulties in IT design and proposes *Grounded Design* as a methodological framework to cope with the complex and sometimes opaque nature of problems in IS research. To this end, the paper is structured as follows: the next section begins with the outline of a theoretical perspective on social practices within organizations. Following this, related research approaches are reviewed. The subsequent section rehearses the principles of Grounded Design as a methodological framework for coping with the wicked problems we detail above. The section after that illustrates these principles by presenting a design case study in which ubiquitous computing application is developed to support the social practices of indoor firefighting. Finally, the last section discusses the results achieved and hints at both limitations and further research.

Practice theory: understanding social practices and change in organizations

Most attempts to classify the paradigmatic positions in IS research tend to distinguish between positivism and interpretivism (Braa and Vidgen, 1999; Goles and Hirschheim, 2000; Becker and Niehaves, 2007), while pragmatism or practice theory as a third basic research paradigm are rarely considered (Goldkuhl, 2012). This epistemological position, reflected for instance in ethnomethodological traditions, is often misunderstood. It is, even so, and as we will demonstrate, of high relevance for IS research.

Positivism seeks to explain and predict what happens in an organization's social world by reducing the investigative scope to searching for regularities and causal relationships among its constituent elements. Positivist research methods are based on 'objective' experimental results predicated on the principle of replicability (often, it has to be said, honored in the breach. See Brannigan, 2004). It should, if well-founded, result in objective knowledge about human behavior when using IT artifacts. In contrast, *interpretivism* attempts to understand the way in which individuals interpret, create and modify the world they are a part of as intentional social actors. Change is thus historically contingent and socially situated, while knowledge is generated through the social construction of meaning (Braa and Vidgen, 1999; Goles and Hirschheim, 2000).

Pragmatism or *practice theory*, as we prefer to name it, is a third paradigmatic position providing a number of basic insights into the socio-technical dynamics of IS beyond positivism and interpretivism. In this perspective, actions change the world, which is understood to be in a state of constant becoming. To perform the desired changes, actions must be guided by purpose and knowledge (Wulf *et al.*, 2011; Goldkuhl, 2012; Kuutti and Bannon, 2014).

In order to achieve more appropriate understanding of underlying problems in IS development, we characterize the

practice-theoretical perspective in more detail. This perspective has been developed, in their different ways, by social scientists such as Bourdieu (1977, 1992), Garfinkel (1984); Giddens (1984), and Mead (1934). While their conceptual work is not at all homogenous, Reckwitz (2002) attempts to identify these core principles of a school of practice-theoretical thinking. According to him, a social practice is understood to be a mainly routinized pattern of human action, which is not only encompassed by mental and physical forms of activity but one that is also mediated by objects, especially by tools, media and their usage. A practice, in this view, is grounded in background knowledge that is not entirely explicit and may be grounded in emotional as well as motivational elements.

Following Reckwitz's (2002) elaboration, social practices are a basic subject for sociological investigations. They represent collective patterns of interaction that are reproduced in specific contexts. The reproduction of practices goes along with a 'for all practical purposes' common perception of the world, common language usage and shared identities.

Such a commitment underpins our research. In doing so, social practices within organizations become the central object of our analysis. Practice-theoretical approaches, deeply rooted in the pragmatist research tradition, are concerned with action and change and the interplay between knowledge, artifacts and action. Accordingly, designing IT systems for effective use in organizations is seen as a multi-layered intervention into social practices. The practice-theoretical perspective offers a thorough and adequate basis to study these interventions (Wulf *et al.*, 2011; Kuutti and Bannon, 2014; Wulf *et al.*, 2015).

Particularly inspired and informed by Giddens' (1984) theory of social structuration (see also Lyytinen, 1990), we adopt this perspective as a reference theory. However, we build on it with some complementary conceptual efforts with respect to the design and appropriation of technical artifacts in the context of organizational practices. With particular respect to IS, we thus develop an analytical framework for investigating organizational social practices when penetrated by IT artifacts. Our theoretical extension specifically allows for the careful analysis and description of both the modeling and design of an IT system's functions, which incorporate aspects of the organization's social practices. Likewise, it allows the investigation of the appropriation of the systems' technical functions for effective practical use in the organization. The extended structuration perspective thereby complies with the demand to pay more attention to materiality in IS research (Orlikowski, 2007, 2009; Orlikowski and Scott, 2008).

In the flow of continued cooperative activity, the members of an organization form a social practice primarily in and through internalized, embodied routines as a product of habituation. Performing a social practice normally also includes handling things such as technical artifacts through which the effects of acting are augmented, while new action routines are formed and internalized or embodied in doing so. These internalized routines equally comprise acts of signification, domination and legitimation; altogether they enable and constrain further acting as taken for granted (Giddens, 1984; Reckwitz, 2002; cf. inner loop in Figure 1).

Performing routines (or appropriating resources) constitutes a set of action conditions (recognized or not) for further acting in ongoing social practices, the effects of which deliver results (intended or not) that (re-)structure routines. In the

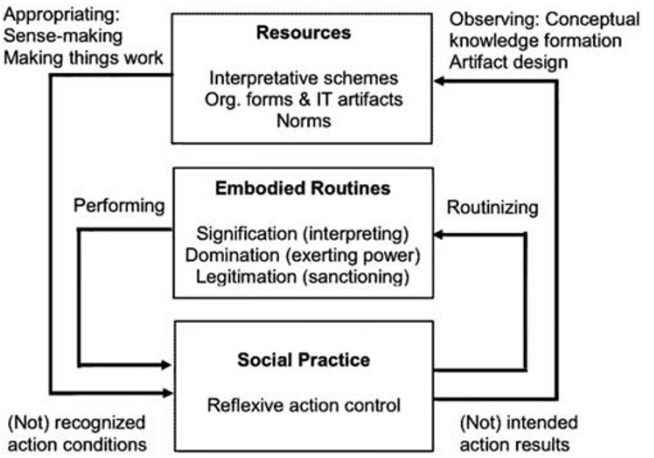

Figure 1 Structuring social practices in organizations.

course of this continuous collective action flow, moments of irritation or surprise may occur, where things that become conspicuous, for whatever internal or external reasons (perhaps because established routines fail), attract specific attention. Such problems lead to a situation in which things normally taken for granted lose their 'objectivity,' since objectivity is not naturally given, but ascribed through shared signification. Moreover, the experienced disorientation in such action crises not only relates to the object, but also concerns the social actors themselves. Obstacles to acting prompt reflection and search process in order to regain the capacity to act appropriately (as e.g. elaborated through notions of 'break-down' and 'reflection-in-action' by Schön, 1983).

Remedy would normally be achieved by reflecting on and conceptualizing routinized action patterns in explicit terms according to the logic of abduction (Peirce, 1935), that is by forming appropriate conceptual hypotheses that provide a 'best fit' with previous experience and knowledge, seeking to explain and to transcend the problematic situation. Actors are able, in this way, to reframe their knowledge and to test their new understanding, to internalize it if proven to be effective, and thus to regain the capacity for effective action. This capacity then also includes the ability to anticipate the possible functions and properties of artifacts, learned from previous actions.

When encountering unknown or newly conspicuous objects, the specific mode of exploratory action is needed in order to disclose and conceive their potential functionality, and to learn how they can be used intentionally. Concepts of the objects' functions and the effects they produce are being formed by remembering the action schemes and their recurrent characteristics. They can be shared by others with similar experiences. Joint interpretation and action in this manner provides a shared interpretive schema. Concept formation thus enables the actors in a social practice to reflect on their activities and to communicate them. By acting and interacting with others in a shared context of social practice, the actors 'create' objects along with their own identity, taking them, ultimately, for granted (Mead, 1903). The use of technical artifacts within the context of social practice is, in this way, 'molded' through the interplay of *modus operandi* and *opus operatus* where both are variably reproduced by the acting itself (Bourdieu, 1977: 72ff).

In this way, the functionality of IT artifacts emerges from objectified conceptual knowledge about social practices. IT artifacts are, as such, used again as a means for further acting. As 'congealed knowledge' being inscribed in their functions and properties, they incorporate formally described aspects of a social practice, and as means of work to practical ends they set specific action requirements for effective use for which they must be appropriated. Appropriation is a complex learning effort of sense-making, of forming new action patterns for putting an artifact's functions to skillful and effective use and of internalizing them as embodied use routines. Appropriation can be defined as new practices or new ways of doing things, which makes things work (Stevens, 2009; Stevens *et al.*, 2012; cf. outer loop in Figure 1). IT artifacts, since they are inevitably derived from abstract, decontextualized knowledge, always contain empty 'slots' that have to be filled in use through 'recontextualization,' that is by interpreting and applying their functions appropriately for given tasks. As the artifacts' functions leave room for interpretation, routines regarding how to handle them properly and their use value are constituted during their practical application. Consequently they are, due to the inherent scope for interpretation, open to diverse practices of usage (Orlikowski, 2000; Brödner, 2009).

Material resources, together with the appropriated routines to handle them, like other internalized action routines (signification, domination and legitimation), constitute social structures that enable and, at the same time, constrain collective acting ('duality of social structure,' Giddens, 1984). By making sense of the resources at hand through interpretation (*signification*), by sanctioning actions according to norms (*legitimation*), by influencing other actors through administrative resources or by shaping activities through the use of IT functions (*domination*), they both develop resources and continuously (re-)create routines that constrain the scope for future action, interaction and negotiation in each of these social practices. The more material resources are adjusted to the action context and the more appropriately they are interpreted and activated for use, the more effective and efficient the social practices of an organization will be (Giddens, 1984; Brödner, 2009).

In sum, humans act with the artifacts at hand by virtue of the meaning they attribute to the artifact's functions and the results they produce. By making sense of and effectively shaping the artifacts' functions in use, specific regularities and use patterns emerge, which become embodied as new routines. Through recurrent interaction with the artifacts at hand, certain of the artifact's functions or properties thus become implicated in an ongoing process of structuration in which rules and routines of use emerge. The resulting recurrent social practice produces and reproduces a particular social structure of artifact use (Orlikowski, 2000). Consequently, the design, appropriation and use of technical artifacts have to be regarded as an integral part of an organization's social dynamics and hence as part of the development of its social practices.

According to the outer loop in Figure 1, designing an artifact's functions and, conversely, appropriating these functions for effective practical use are both creative actions and are logically based on abductive reasoning. Design hypothetically creates potentially useful, usable and efficient functions informed by design-oriented knowledge (*what could work in this situation?*). For its part, appropriation hypothetically creates effective ways to use the artifact's functions, informed by experience *(how and how well does it work?*). If these exploratory acts of usage prove to be successful, they become internalized as routines and integrated in social practices that will, in turn, be restructured by this process (inner loop in Figure 1). Design objectifies explicit knowledge about social practices, while appropriation makes restructured practices durable. Observing and reflecting on appropriation finally leads us to 'design relevant explanatory/predictive' knowledge (Kuechler and Vaishnavi, 2012: 396), complementing insights derived from prescriptive IS design theory (*why does it work?*).

Related approaches in IS research

The practice-theoretical perspective outlined above has a number of far-reaching consequences for IS development. In particular, attempts to model the use contexts of IT artifacts lead to the *representation dilemma* of trying to understand the real needs and intentions of human actors in social practices on the one hand and the necessity to formally represent them by means of deterministic algorithmic descriptions on the other. As Lucy Suchman (2007) – in accordance with the practice-theoretical perspective – elaborated in her seminal work on plans and situated action, human actions in social contexts are driven by complex expectations and interpretations, which make their results contingent, unpredictable and non-deterministic. IT artifacts, as algorithmic machines, are unable to cope with this. Social contexts are not stable and fixed, but are rather constructed by social actors in and through their own actions, interactions and experiences; thus they are continually reconstructed and renegotiated through interaction within their social practices. This implies two paramount consequences for the process and methodology of designing IT artifacts.

First, IT systems are not just models or representations of the organization's social practices but rather serve as supportive artifacts that, in the course of participatory organizational development, must be co-designed, appropriated and enacted for effective use together with other formal structural or procedural resources (integrated organization and technology development (OTD); Wulf and Rohde, 1995; Brödner, 1998; Rohde, 2007). It is then up to the users – not the designers to interpret the meaning of the organizational forms and the functions of the IT artifacts in use, since this meaning cannot be specified in advance. Design and appropriation activities thus intervene, in a self-referential circle, in the social practices for which the IT artifact's functions are modeled and designed. Consequently, the effects produced are not solely dependent on the functionality of the implemented system but are also a result of how they have been appropriated and put to effective use in practice. Design quality can, therefore, only be evaluated in the context of use practices.

Second, as the design of IT artifacts is a reflexive endeavor in the sense that the artifacts' appropriation and use change the organization's social practices that they were designed for, frequent changes of functional requirements during system design and implementation are inevitable. Design methodology must therefore cope with this inescapable fact and organize design and implementation processes in a reflexive and evolutionary way with iteratively revised and improved versions of the artifact each time leading to a new social practice (cf. Figure 1).

In the pragmatist tradition of IS research, *action research* plays a prominent role for improving IS design. Action research generates theoretical knowledge for and understanding of organizational development through direct researcher interventions to improve system performance (Baskerville and Wood-Harper, 1998). Specifically, the principles and procedures of *canonical action research* (Davison *et al.*, 2004) or *grounded action research* (Baskerville and Pries-Heje, 1999) attempt to bring more rigor into the process of theoretical knowledge formation. The underlying cyclic scheme of diagnosing practices, iteratively forming hypotheses about interventions, then testing and evaluating them in practice resembles some procedures derived from DR and suggests that action research and DR might cross-fertilize each other, particularly as both have pragmatist roots (Cole *et al.*, 2005; Lee, 2007; Baskerville *et al.*, 2009; Goldkuhl, 2012). While this relationship is seen as somewhat controversial in the literature (cf. Iivary and Venable, 2009), IS design, and artifact design efforts in particular, receive scant attention in relation to the action research (AR) cycle of building, appropriating and evaluating an artifact's functions for knowledge formation. Specifically, Baskerville and Pries-Heje (1999) concentrate on integrating techniques from grounded theory into action research in order to gain a more rigorous and reliable approach to theory formulation for studying organizational change. To achieve additional methodological rigor, Davison *et al.* (2004) concentrate on elaborating canonical action research principles for similar reasons. These approaches, that is, with their specifically theoretical focus, do not pay sufficient attention to the representation dilemma and the self-referential nature of design interventions as they consider the design of IT artifacts and their appropriation only marginally, specifically omitting to address their intricate and contingent nature.

Attempting to improve clarity about diverse IS research methods, Braa and Vidgen (1999) present a research framework for in-context research. They use this framework for positioning 'pure' and hybrid forms of research methods in an ideal-type manner. The authors argue that 'pure' modes of investigation have the merit of providing explanatory power but do not, of themselves, provide design solutions. Some combination of research and intervention is needed. Change can only be the outcome of intervention (there being an implicit assumption that such change will be beneficial). Successful changes will, in turn, produce new interpretations and understanding. Hence, from this point of view, case studies serve as interpretive schemes for gaining insights and understanding of social practices while action research supports intervention by generating the knowledge with which to manage the desired changes. Using this framework, 'action cases' are presented as a hybrid research method combining the interpretive case study approach with action research as the method of intervention.

Concerned with improving the way IS research is conducted, Mathiassen (2002) rethinks the plurality within ISR's methodology in a similar way – referring explicitly to the above typology. He addresses the key issues of research practice, such as respecting the situatedness of local environments, improving interpretive understanding and considering normative elements. He concludes that the collaborative efforts of IS researchers together with practitioners have to be studied under the dual imperative of improving social practices as well as generating knowledge in the form of theory and method. To this end, Matthiassen (2002) proposes collaborative research in close cooperation between researchers and practitioners throughout the whole change process, which he labels 'reflective system development.'

Both approaches are much in line with the practice-theoretical paradigm presented in this paper. They consider IS development as intervention, which produces desired change while at the same time generating appropriate understanding of social practices. However, their approach to action research puts too little emphasis on the way in which artifact functions are appropriated and does not sufficiently address issues of knowledge-based IT artifact design. These issues require more attention, as design and appropriation are both modes of contingently intervening in social practices (albeit not always by the same actors).

In contrast to this, Sein *et al.* (2012) propose *Action Design Research* (ADR) as a new method to address the problem that IT artifacts 'emerge from interaction with the organizational context even when its initial design is guided by the researchers' intent' (p. 37). The ADR method 'conceptualizes the research process as containing the inseparable and inherently interwoven activities of building the IT artifact, intervening in the organization, and evaluating it concurrently' (p. 37), thus constituting an evolutionary approach. The method 'deals with two seemingly disparate challenges: (1) addressing a problem situation encountered in a specific organizational setting by intervening and evaluating; and (2) constructing and evaluating an IT artifact that addresses the class of problems typified by the encountered situation' (p. 40).

We explicitly share the theoretical perspective and the evolutionary procedure the ADR method is built on. However, based on our long experience with action research in IS domains and drawing on insights from practice theory, we challenge the view that the second proposition can actually be achieved. To begin with, according to the practice-theoretical perspective, artifact design is a creative activity that seeks to satisfy requirements or needs emerging from 'irritated' social practices rather than an act of identifying or formulating a more or less abstract problem (cf. also section 'working on the artifact'). Progressing in IS research projects often leads to a change in requirements, eventually also to a new understanding of problematic practices differing from what has been conceived beforehand as being similar or comparable to other cases or even seen as an instance of a class of problems (cf. the demonstration case below). Rather than *a priori*, this can normally only be done *a posteriori* when reflecting on, analyzing and explicating the specific case in decontextualized terms. In general, the nature of design as a 'wicked problem' (Rittel and Webber, 1973) *a priori* hides the class of problems the specific case might belong to. Moreover and most importantly from the practice-theoretical point of view, the approach does not extensively consider the collective appropriation of the designed artifacts, of learning to make sense of their functions and putting them to effective practical use as another relevant source of contingent intervention in social practices. These reasons lead us, notwithstanding the similarities, to propose Grounded Design as an approach to deal with these issues.

There is a continuing interest in DR due to unresolved concerns about the outcome of the design process, the role of theorizing and how to conduct evaluation (Hevner *et al.*, 2004; Goldkuhl and Lind, 2010). In their *Multi-grounded Design*

approach, Goldkuhl and Lind (2010) propose a grounding process to generate valid knowledge from the DR process. This approach is based on the division between meta-design, which produces abstract design knowledge (e.g. design principles, constructs), and empirical design practice producing situational knowledge and artifacts as unique 'design cases' (e.g. models, IT artifacts). This contributes to DR '(1) through design as a solution to practical problems and people's needs and (2) also to knowledge goals of a scientific community' (48). On the situational (i.e. practical-empirical) level, design actions produce situational design knowledge expressed in models and IT artifacts as instantiations that are empirically grounded in practical knowledge concerning problems, needs, opportunities or goals on the one hand, or use effects on the other. This design practice is additionally grounded at a theoretical level in abstracted design knowledge (e.g. constructs, principles, values, methods or theories) that may for their part also be informed by other theories (such as e.g. practice theory).

With their *Soft Design Science Methodology,* Baskerville *et al.* (2009) present an IS DR approach for artifact design. This involves forming design hypotheses, experimenting with the designed artifact and comparing the results with expectations in a design-build-evaluation loop. This cycle may be repeated in an iterative process until the desired utility is achieved. A key feature of soft design science research is the division between design thinking and real-world activities. While a specific problem situation is identified and expressed as a set of specific requirements in real-world terms, these requirements are systematically abstracted into a general problem leading to a general design solution, expressed as general requirements in the design thinking domain. These general requirements are then compared with the specific problem to fit in the real world again. A declarative search is then made to obtain the specific components of what are deemed to be workable solutions to the problem. An instance of the specific solution is finally constructed and deployed into the social system, leading to an improved situation (here the cycle could start again).

Both Multi-grounded Design and Soft Design Science Methodology provide similar approaches to DR, addressing both the situational and the decontextualized knowledge level. Through the iterative activities of design, development, instantiation and functional evaluation of technical artifacts, theoretical design knowledge for improving social practices in organizations is gained, including consideration of social aspects. In the end, the derived artifact is claimed to represent a general solution to a class of problems exhibited in one instance of that class of problems. In this way, these research approaches generate IS design knowledge as well as procedural guidance for design processes.

We widely share this general perspective in our approach, *Grounded Design*, particularly with respect to the iterative design-build-evaluate loops, and the differentiated consideration of situational and decontextualized knowledge. However, we question the claim that the derived artifact represents a general solution to a class of problems: whether this is the case cannot be decided *a priori* because contingent factors, and different avenues to appropriation, will intervene. We argue that IS research necessarily needs to focus on the appropriation of an artifact's functions for effective practical use. Appropriation activities need to be understood by users as contingent creative action with the potential to restructure social practices in a unique way. The reflective analysis by users offers a major source for generating 'design relevant explanatory/predictive' knowledge, explaining 'why the artifact has the effects it does' (Kuechler and Vaishnavi, 2012: 396). Generalization to acquire prescriptive knowledge for IT design from our perspective is only possible *ex post* by comparing the similarities and differences of given design case studies and disclosing common features or configurations.

Table 1 summarizes the comparative differences between the IS research approaches we have looked at by systematically comparing them according to several relevant aspects from the practice-theoretical perspective.

Principles of Grounded Design

Grounded Design is an IS research approach that takes a practice-theoretical perspective. We see it as overcoming some of the problems presented by the approaches discussed above. Taking this perspective, DR needs to be understood as a complex intervention in established social practices (cf. section 'Practice theory: understanding social practices and change in organizations' and Figure 1). In the course of such interventions, social practices are partially developing by adopting and embodying new ideas, formal schemes or technical functions for skilful use.

The sequence of analyzing procedural aspects of social practices, defining functional requirements, designing IT artifacts and appropriating their functions for effective use contains a number of creative activities. They present a rational alternative to methods derived from theoretical knowledge on IT design. In particular, and to reiterate, the design of IT artifacts as well as the appropriation of their functions, although they may be guided and informed by theoretical knowledge, are complex, creative and situated activities. They are based on human intuition and their effects on social practices cannot fully be foreseen in advance.

Consequently, design and appropriation activities are hypothetical in nature and need to be performed tentatively by exploring potential effects, while their utility or significance can only be proven through practical use. The principles of Grounded Design were first sketched out by Stevens (2009) and further elaborated by Ramirez (2012). The approach was not developed from scratch, but is rather rooted in the conception of OTD (Wulf and Rohde, 1995; Rohde, 2007) as an action research approach dedicated to developing supportive IT artifacts and framing their appropriation by facilitating change processes and supporting self-organized activities by its users. Moreover, Grounded Design builds on Business Ethnography, an ethnographically oriented action research approach that specifically focuses on the relation between practical intervention and theoretical reflection (cf. Nett and Stevens, 2008; , Rohde *et al.*, 2009; Stevens and Nett, 2009).

Methodologically, these facts are reflected by the principles of Grounded Design where theory building is based on reflective intervention in social practices (Rohde *et al.*, 2009):

- Initially, reflection on the irritations of the present situation takes place. Actors are looking for answers to the questions *what might be a problem?, which technical options are at hand?* and *what could work?* Analyzing existing practices, a shared understanding of the present situation as well as of

Table 1 Comparing IS design research approaches

Approach	*Design: Working on artifact*	*Appropriation: Working with artifact*	*Building the knowledge base*	*Methodology*	*Research result*
Grounded or Canonical Action Research (Baskerville and Pries-Heje, 1999, Davison *et al.*, 2004)	Hypothetical artifact design	Impact of appropriation on intervention is not considered	Increase rigor & reliability of theory formulation in AR by integrating canonical AR with grounded theory principles	Action research	Rigorous & reliable method for performing AR cycles
Action Cases (Braa and Vidgen, 1999)	Not explicitly considered	Impact of appropriation on intervention is not considered	Creating general knowledge for organizing interventions	Action research combined with case studies	Action cases & research framework
Collaborative Practice Research (Mathiassen, 2002)	Not explicitly considered	Impact of appropriation on intervention is not considered	Creating procedural knowledge for improving social practices	Collaborative action research	Collaboration principles in AR
Action Design Research (Sein *et al.*, 2012)	Hypothetical artifact design guided by theoretical design knowledge	Impact of appropriation on intervention is not considered	Creating theoretical knowledge on artifact design, matching design solutions with problem classes	Action design research: building IT artifacts, intervening in organizations & concurrent evaluation	Practical solutions & theoretical design knowledge
Multi-grounded Design (Goldkuhl and Lind, 2010)	Hypothetical artifact design guided by meta-design	Impact of appropriation on intervention is not considered	Creating augmented theoretical knowledge on artifact design from design cases	Deriving meta-design principles from design cases & other theoretical sources	Situated design of artifacts & general design & procedural knowledge
Soft Design Science Methodology (Baskerville *et al.*, 2009)	Hypothetical artifact design guided by design knowledge	Impact of appropriation on intervention is not considered	Creating theoretical knowledge on artifact design, matching design solutions with problem types	Testing hypotheses in design-build-evaluate cycles	Situated design of artifacts & general designs & procedural knowledge
Grounded Design (Rohde *et al.*, 2016, this text)	Tentative artifact design to satisfy requirements grounded in practice	Generating new design ideas by means of formative evaluation of artifacts in use	Creating abstract designs on artifacts & procedural knowledge by explicating & comparing design case studies	AR-based design case studies & *ex post* extraction of common features	Improved social practices & corpus of situated design case studies subject to meta-analysis

potentially useful IT functionalities emerges. Requirements for and restrictions to improving the practices can be explicated.
- After design, implementation and appropriation of innovative IT artifacts, the question *how and how well does it work?* needs to be answered. It leads to a formative evaluation and a shared understanding of the changed social practices.
- Reflecting on the emerging case and answering the question *why does it work?,* a design case study (Wulf *et al.*, 2015) is documented at last. It provides explanations in explicit terms as to how and why the change process has been initiated, what the relevant measures in retrospect have been and how they have become effective.

Pre-study/context study

A Grounded Design research approach requires close collaboration between researchers and practitioners. To establish the basics for such collaboration, a Grounded Design project requires a *preliminary initialization phase* in the form of a pre-study or context study, an initial, participatory-ethnographic inquiry of the anticipated application context, in which researchers gain a thorough understanding of the social practices under consideration. This also helps to develop an adequate project language for communicating with the practitioners. This starting phase ends with a shared understanding of the social practices and the aspects to be improved.

Working on the artifact

Social practices in an organization are normally taken for granted and their well-established routines are performed for the most part without reflection unless some kind of internal or external irritations occur. Dissatisfaction with existing routines, frustrated expectations, changes in the market context or new ideas from outside may cause sufficient irritation to reflect upon existing practices. In the context of our work, we are specifically interested in irritations that are provoked by the opportunities furnished by new technologies. Appropriate design of these technologies may allow the rethinking of practices in the course of the IT artefact's appropriation.

To design the artefact (*working on the artefact*), the first step required is to establish a case that is a – possibly academically – facilitated IT design, and to develop the project with a (broadly) defined focus. This serves as necessary legitimation for possible interventions as well as a framework for observing and analyzing existing social practices within the organization with the aim of impacting on performance.

Frequently (however not necessarily), such design cases are initiated by researchers' or practitioners' desire to jointly explore the potential of innovative IT devices or features to enhance existing practices. In such cases, ethnographical analyses are needed in order to assess the prospects for appropriate new IT artifacts relative to the organization's social practices. This kind of analysis delivers a preliminary approach to answering the questions *what do we need*? to improve the situation and *what could work?*

Discursive activities regarding design knowledge in respect of possible answers to these questions can then produce the first bundle of functional requirements for designing IT artifacts and for corresponding organizational development. Equally, it could transpire from this analysis that designing new IT artifacts or developing new organizational structures is not an adequate approach and that performance could instead be improved by cultural shifts (changing, for instance, leadership behavior or collaborative practices). Overall, the ethnographical analysis grounds the IT design.

When it actually comes to participatory design efforts, it is important to recognize that basically, design is a creative (as opposed to an analytical) mapping activity. This mapping relates the functional space of socially determined requirements (what is desirable) to the physical space of design parameters (being technically feasible and accessible for intentional control) (Ackerman, 2000). As a creative process, the construction of this mapping goes far beyond scientific knowledge and can, at best, be guided by design knowledge such as heuristic rules or design principles derived from previous design experience. Design may, then, be defined as the creation of artifacts whose synthesized functions (in the form of models, products, processes or systems) satisfy perceived demands while respecting given restrictions. This mapping is non-unique, that is more than one design may satisfy the functional requirements (Suh, 1990; Smith and Browne, 1993), and its utility needs to be assessed by users in practice. Design science in this perspective should be understood as a discipline having social design activities and processes as the main subject of its cognitive interests (Cross, 2001).

While from a positivist perspective design is normally understood as an optimization problem under constraints (Simon, 1969), the practice-theoretical perspective conceives design as a 'dialogue' within the social context situation. Similarly, Rittel and Webber (1973) regard 'problems of social policy' such as designing artifacts for IS development as 'wicked problems,' implying that every solution is a 'one-shot operation,' which consequentially leaves 'traces' that cannot be undone. Wicked problems are essentially unique in that they are not resolved by scientific approaches, in much the way that design theory 'under-specifies design' (Gaver, 2012).

Nevertheless, design activities can be guided and informed by a sound knowledge base of either practice-based insight or theory, although technological design activities fundamentally differ from analytical activities in science. While science strives for cognitive validity, technology aspires to create useful and usable as well as effective and efficient artificial systems (Poser, 2001; cf. Table 2). While scientific cognition is based on rigorously testing theoretically informed hypotheses (in large part) by controlled experiments, technology design is proven through achievement in use when its artificial systems satisfy defined requirements.

Technological development, as we have shown, is based on the interaction of cognition and design. Cognition produces

Table 2 Differences between science and technology design

	Analytical science	*Technology design*
Objective	Cognition (concept formation)	Utility (functional capability)
Subject	Natural phenomena	Artificial systems
Method	Controlled analysis	Synthesis (structure & functions)
Result	Theory	Heuristic design rules
Quality	Viability	Achievement

potentially useful theoretical knowledge that can be used in artefact design for pre-use testing, for example in providing evidence that a mechanical device has sufficient static and dynamic stability. Design creates artifacts that, when achieved in use, may in turn contribute to cognition, for example in reflecting and analyzing the failures of stability (Poser, 2001). In the case of humans interacting with IT artifacts, design may likewise be based on psychological knowledge in relation to how to present data on organizational objects or processes, the efficacy of which may then be evaluated in use and may again contribute to IS research knowledge.

Technical artifacts with well-defined causal functions produce effects that are solely determined by the activating input. The functions' output, however, that is the artifact's intended effects, then needs to be interpreted by the users within the context of their social practices in order to put it to effective use for achieving given tasks. In fact, the entirety of an artifact's functionality forms a sort of 'functional language.' In order to reasonably activate the appropriate functions, users need to learn to express their intended use actions by means of the artifact's functional language 'vocabulary.' This is an essential part of the appropriation process.

Working with the artifact

Appropriating new functions of IT artifacts for practical use is another creative activity. It compels users to explore opportunities for changes in their practices. The emergent achievements of these exploratory activities strongly depend on the routines associated with previous social practices. This is why, on the one hand, significant sense-making and learning efforts are needed when adopting an IT artifact's functions for effective use, and why appropriating the same functions may, on the other hand, lead to different practices and routines (Orlikowski, 2000).

Since appropriation of IT artifacts for effective use (*working with the artifact*) normally requires high collective learning efforts, it might appear useful to supply some technical support for making appropriation processes more efficient. Various approaches for methodological or technical appropriation support have therefore been devised and implemented with respect to workplace integration, sharing activities and augmenting tool knowledge. The spectrum ranges from integrated tutorials that assist users in experimenting with functions, through annotated configuration for finding suitable system adaptations to explorative interaction for learning safely functional effects (Wulf, 2000; Pipek, 2005; Draxler *et al.*, 2012).

Moreover, these collective learning processes may be deliberately initiated and organized by external facilitation. Since these processes essentially aim to change social practices by adopting and embodying new use routines, the most effective sense-making and learning method is to already involve the users in reflective discourse on existing practices and envisaged design requirements. While trying to make sense of specific new functions for accomplishing their operational tasks, users will open their minds to consider new ways of doing things and they will also learn to generate further practice-oriented requirements for an improved version – following the principle of *learning by designing*. Such activities can be based on and take advantage of the long tradition of participatory design (cf. Schuler and Namioka, 1993; Mathiassen, 2002).

Finally, the usefulness and usability of new IT artifact functions need to be evaluated. Their usefulness and usability, we consider, can only be thoroughly assessed through real use in the social context of the practices being restructured by this process. There are methods of formative evaluation involving the participation of users and designers to achieve this. A formative evaluation will indicate whether the artifact design and appropriation have generated satisfying social practices as compared to the original objectives agreed upon, or it will deliver further design ideas to be worked out in the next phase. Evaluating the use of the IT functions in the context of resulting new social practices is thus a major source for the generation of relevant design ideas.

Building the knowledge base

Design and appropriation processes are accompanied by activities of observing and reflecting upon the IT artefact and the design process, as well as upon the development of social practices performed in the course of the artefact's appropriation. The latter is mainly based on analyzing and logically reconstructing, in minute detail, the ways in which practices are produced in their natural order (Garfinkel, 1984; Schmidt, 2011). Observation and reflection thus deliver explicit conceptual knowledge about tentative design considerations on the artifact and the learning processes associated with them with respect to the question *what could work*? This knowledge can best be condensed in the form of an explicated *design case study* (Wulf *et al.*, 2011, 2015) describing the original social practices, the design discourse, the design options considered, the appropriation process, the effectiveness of the artifacts' functions and the emerging new social practices according to the analytical framework presented in Figure 1 – paying particular attention to the analytical aspects of signification, legitimation and domination in the emerging organization's social practices on which the shape and not least the performance of the IS largely depend.

Such design case studies serve as explicit conceptual reconstructions of the organizational change process that answers the question *why is it working?* They thus contribute to design-relevant explanatory/predictive knowledge according to Kuechler and Vaishnavi (2012) as necessary complementary knowledge to IS design. Design case studies of this form may then be collected in an *IS design knowledge base* and, during further research – and given a rich body of existing design case studies – can become the subject of a comparative meta-analysis.

Meta-analysis

If a sufficient number of design case studies have been gathered, they may additionally undergo *meta-analysis* with the aim of identifying cross-sectional similarities and differences (Wulf *et al.,* 2015). This might lead to some common patterns or features of design cases that can be typified.

Regarding the fact that both the artifact design and the associated appropriation processes comprise creative activities with various choices and unforeseeably open results, it is clear that each design case study is unique. Due to the creative nature of the artifact's design and appropriation, its effects on social practices cannot be envisaged in advance. Each case is different, even if the same IT artifacts are being used. In passing, in IS DR, this is also the main reason why it is not possible to assess in

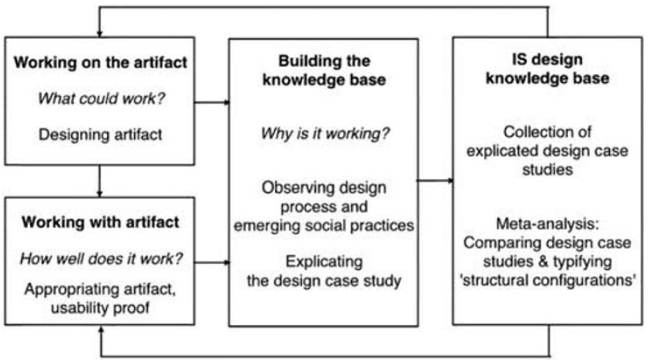

Figure 2 Overview of Grounded Design principles.

advance whether a case is typical for a certain class of problems, as demanded by Sein *et al.* (2012). Nevertheless, a knowledge base containing explicated case studies based on this type of interpretive DR may offer transferable knowledge for other IS design cases by typifying common 'structural configurations' in the IT design space and the social practices at stake (Walsham, 2006; Rodon and Sesé, 2008). Such knowledge may guide design activities with respect to specific properties or requirements of social practices, or provide orientation for necessary appropriation activities.

So far, we have argued that the IS design knowledge base envisaged in this paper has great practical value, as the different in-depth design case studies contain rich contextual information about social practices. This provides orientation knowledge and this knowledge can be used for guiding design discourses and learning processes during appropriation (cf. Figure 2 providing an overview of the Grounded Design principles). It offers a community of IT designers' 'annotated portfolios' as suggested by Gaver (2012) as an alternative to design theory approaches. In contrast to Gaver's (2012) suggestion, however, our portfolio of design case studies focuses specifically on design and appropriation activities.

Evolutionary project organization

Since the design and implementation of IT artifacts are *reflexive endeavors* in the sense that appropriation and use of the artifacts' functions intervene in the social practices they are designed for, frequent changes of functional requirements during system design and implementation are inevitable. Hence project management and software engineering methodologies must cope with this inescapable fact and organize design and implementation processes in a reflexive and evolutionary manner with iteratively revised and improved prototypes or versions of the artifacts. Evolutionary project organization allows for combining the IT design (respectively configuration) efforts with the collective learning efforts for putting the system to effective use.

This requires sound methods of software engineering and evolutionary project management that combine aspects of modular design, formative evaluation and collective learning in iterative development loops.

Given the artifacts' embeddedness in the organization's social practices, these efforts are always subject to micro politics. This fact is frequently disguised by hiding aspects of domination behind arguments of signification in design discourses. Project management should therefore take particular care that the actors involved negotiate transparently in favor of synthesizing their different views and of balancing their diverse interests (Nett and Stevens, 2008). Rather than smoothing these differences out, they need to be dealt with explicitly; if not, we believe, the consequences will be disappointing. Moreover, as IS design means intervening in social practices, there is an evident need to justify choices as a legitimating maneuver if resistance is to be avoided.

The corresponding research process guidelines are summarized in Table 3.

Developing systems in support of indoor firefighting – an example of two successive design case studies

Our continuing research experience in developing IT-based support for firefighters operating indoors may serve as a suitable series of design cases to illustrate the significance and application of the Grounded Design principles for complex IS projects. The research effort comprises almost seven years of work in participatory design based on 'ubiquitous computing' technology (Weiser, 1995) involving four different fire brigades in France and Germany. The practice-centered perspective, as we see below, shifted the design focus during these projects. Based on a thorough observation of the firefighting routines, the design focus shifted from automatic location detection to technical support for computer-enhanced way-finding practices in reconnaissance missions. We finally augmented the way-finding platform by adding functionality for a highly structured communication channel (for more project details and the resulting brief case presentation see Ramirez *et al.* (2012) and Betz and Wulf (2014)).

Design case study: Landmarke – navigation and orientation support for firefighters

In the case of fire incidents, indoor reconnaissance missions are an essential part of firefighters' work. In such missions, a team of firefighters enters an unknown building in order to systematically inspect and assess the situation; to simultaneously look for victims, report on progress and eventually to attack fire sources. Due to the heat and fumes, firefighters have to wear special protective suits and breathing protection equipment that provide support for restricted periods of time only. Moreover, they have to drag along heavy fire hoses for attacking possible fire sources and for guiding their way out. Inspection entails complex cooperative work, requiring considerable training and experience. It imposes a high work load with the additional impediment of severely restricted mobility due to both the protective and the firefighting equipment. In particular, safely finding a way out before exhausting the air supply is of existential importance, as getting lost is a frequent cause of severe accidents. Longer lasting reconnaissance missions require alternating inspection teams that calls for space-related communication between the teams and the operation controllers.

Pre-study/context study: investigating existing practices

The research began by investigating existing firefighting practices. On the one hand, it drew on psychological knowledge about way-finding and, on the other hand, it was based on a thorough ethnographical study (by participatory observation and interviews) of existing social practices for indoor tactics in firefighting. The study reveals various complex

Table 3 Research process guidelines

GD principle	*Research process guideline*
Pre-study/Context study	Start project with an ethnographic study of existing social practices: • Create a shared understanding of the problematic situation. • Establish communication schemes for collaboration between researchers and practitioners. • Reflect on and explicitly document the results.
Working on the artifact	Designing and implementing the artifact's functions: • *What could work in the problematic situation as we see it at present?* • Reflect on and explicitly document the results.
Working with the artifact	Appropriating newly generated functions of the artifact and evaluating their usefulness in a restructured practice: • *How and how well do the artifact functions work in context?* • Reflect on and explicitly document the results.
Building the knowledge base	Reflecting on the whole process through conceptual reconstruction on the basis of documented intermediate results explaining: • *Why is it working?* This delivers a comprehensive *design case study* describing the original social practices, the design discourse, the design options considered, the appropriation process, the usability and efficacy of the artifacts' functions and the emerging new social practices – paying specific attention to the analytical aspects of signification, domination and legitimation as basic components of the knowledge base.
Meta-analysis	Looking for similarities and differences across design case studies, identifying patterns and typifying 'structural configurations.'
Evolutionary project organization	Organize the IS development project on the basis of • close collaboration between researchers and practitioners; • an iterative, evolutionary process running through (eventually several) loops of generating design ideas, prototyping, implementing and appropriating the functions of the artifact and formatively evaluating the resulting situation.

inspection and way-finding practices that were not always immediately obvious and can be described as follows:

The interactive exploratory teamwork based on distributed tasks has to be done under difficult environmental and sensorial conditions due to heat, fumes and heavy protective equipment, forcing the team members to interact and to constantly keep in touch, mainly through body contact, lifelines and fire hoses carried with them. To maintain orientation, they follow the 'right hand rule,' a systematic approach comparable with 'depth-first' traverse algorithms as a basic exploration strategy. While exploring the actual situation and the spatial structure in this way, the firefighters build cognitive maps based on meaningful 'landmarks' (such as walls, aisles, doors or windows) during the progress of their mission. To enable leaders in front of the building to participate in the construction of such a representation of the incident place, firefighters working indoors report their decisions and important milestones of their progress to their leader outside via radio devices. Landmarks and milestones may be actively augmented with additional signs to denote specific results of their exploration, for example signs that stand for 'already inspected' or 'alternative way out.' The situation-specific cognitive maps thus provide them with a shared reference for maintaining awareness of the environment, for orientation and communication, for finding the way out, and for instructing follow-up or rescuing safety teams in case of an accident. This demonstrates how initial assumptions on the part of researchers were naïve and even mistaken. Their design idea to provide the firefighters with navigation software for position determination turned out to be inappropriate or in the worst case was considered harmful: Firefighters fear losing their navigational skills and competences by using map- and positioning-based navigation tools.

Design and appropriation phase: working on and with the artifact

The main design and appropriation phase of the research project builds on the contextual pre-study and follows a participatory and evolutionary process organization. It is based on a sequence of specification and prototyping workshops with firefighters and firefighting instructors in order to generate design ideas for technical artifacts supposed to improve their demanding work situation. As conceived by the researchers, small, wearable, ubiquitous computing devices promised to be fruitful in this case.

During the workshops, the ability to participate, contribute their own experiences and thereby improve the situation proved to be sound motivation for the practitioners. Reflecting on their own practices and when presented with functional prototypes of suitable artifacts by researchers (or designers) turned out to be an important source for generating new design ideas. In this way, a number of sound design ideas have been contributed by firefighters. Moreover, such participatory procedures help to solve

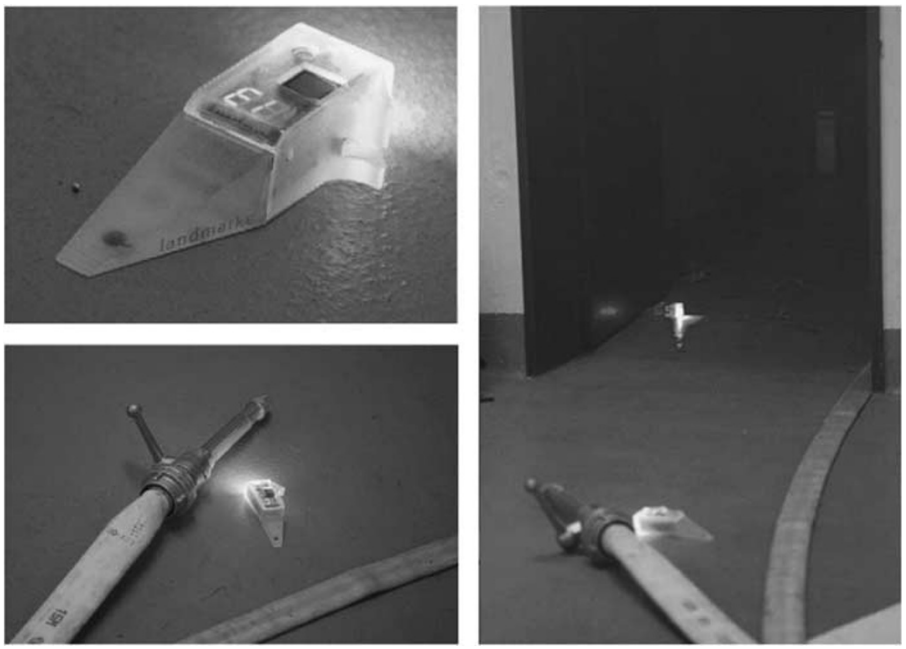

Figure 3 Building an electronic grid to support orientation and space-related communication.

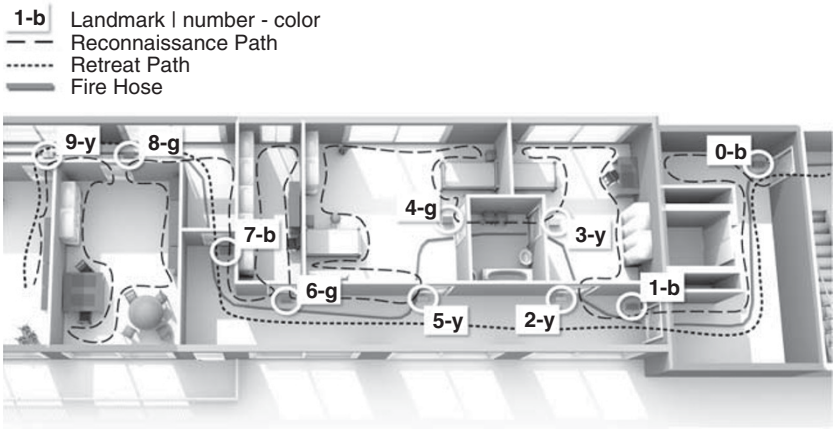

Figure 4 Analysis of a trial reconnaissance mission.

signification and legitimation problems, emphasizing the requirements of the firefighters in this regard.

Inspired by the firefighters' existing social practices with regard to the different forms of marking and annotating spatial objects and structures, artificial 'landmarks' with sufficient functionality for use in electronic networks are being conceived. The core idea is to successively build an ad-hoc reference system on site, which will be continually constructed during firefighting missions. The system is progressively built up and augmented by intentionally deploying an electronic grid of small networked tokens that serve, when deployed, as reference points representing tactical information about the site and the progress. They support spatial orientation and space-related communication among the firefighting teams and the outside coordinators as well. When equipped with suitable sensors, they further enrich emerging cognitive maps with situational and environmental information (cf. Figure 3).

As envisaged by the evolutionary project organization, several variations of the electronic 'landmark' tokens with different functional complexity have been designed and appropriated stepwise for practical use in reconnaissance missions in a training center where the emerging new practices can be observed and evaluated. Each of these prototype versions has been tested in this way and evaluated in practical use, from which new design ideas have been generated.

One notable result of this whole procedure is that, by the intentional deployment of tokens, firefighters are able to construct richer cognitive maps of the site than before: the numbered sequence of electronic landmarks not only indicates locations but also provides additional context information coded by color. Having this sort of artifact at hand means they can partially avoid having to drag heavy fire hoses along with them, and they can also improve their spatial orientation and navigation due to the enriched context information. This further enables them to substantially shorten the retreat path as shown in Figure 4 comparing old and new practices.

By the end of the project, and based on the experiences they gained during the participatory design and appropriation process, the firefighters were fairly able to judge the strengths and weaknesses of their own practices. While they appreciated

the mutual leaning and reflection process, they expressed concerns as to whether the Landmarke platform offered enough 'added value' compared to the additional effort caused by the deployment of the beacons. Nevertheless, the firefighters appropriated the beacon's color codes to deal with the problem of the unstable connectivity of their voice-over-radio communication between indoor working teams and their commander outside the building. We observed how they used the feature to remotely set the color of each beacon to articulate simple requests like 'Everything ok?' and their responses, like 'Yes' or 'No.'

Thus the appropriation of the platform for navigation support led to the disclosure of other, probably even more immediate, problems of indoor firefighting. Reflection on the existing situation formed a knowledge base that served as a platform for further investigations into other aspects of the observed social practice. In our case, we extended the ethnographic work towards communication and coordination between firefighter teams working indoors and their commanders outside the building.

Design case study: Koordinator – coordination and communication support for firefighters

A second project, called 'Koordinator,' was derived from the design knowledge base originating in the 'Landmarke' project to create a design case study to work on artifacts for communication and coordination support and to investigate the appropriation of these artifacts (Betz and Wulf, 2014).

Pre-study/context study: investigating existing practices

As in most countries, firefighters in Germany utilize radio sets to establish voice communication between indoor operating units and the command structure outside. Based on knowledge accrued from the 'Landmarke' design case study as well as a complementary pre-study/context study in cooperation with various (mainly German) volunteer fire brigades over a time span of more than 3 years, the advantages and disadvantages of the current voice over radio communication tactics and techniques were analyzed.

It emerged that navigation, communication and coordination practices are interwoven across many dimensions. Requirements from firefighting, regulatory and systematic reconnaissance approaches form routinized and partly formalized patterns of communication and coordination, which can be anticipated to a very large extent.

Design and appropriation phase: working on and with the artifact

The 'Koordinator' design case study builds upon the network infrastructure implemented in the 'Landmarke' design case study and extends the design of the 'landmarke-remote-control' with communication features. Since the major parts of the communication system and also the technical constraints of the ad-hoc deployable landmark-infrastructure could be anticipated, a shift from voice- to text-based communication was implicated. The resulting complementary messaging device and its appropriation have been evaluated in 13 full-scale training missions including extensive debriefings. The debriefing sessions in particular afforded the opportunity for intensive participation and steering by the firefighters.

Adding communication features to the original 'Landmarke' navigation support system led to the 'added value' required. The resulting integrated artifact designed in the 'Koordinator' case study was assessed as valuable enough for the introduction of an integrated system as official firefighting equipment. The main reason for this change of mind lies in a better cost-benefit-balance regarding the addition of a further piece of equipment *vs* the efforts associated with the manual deployment of the 'landmarks.' In particular, the appropriation of the 'Koordinator' IT artifacts reduced both their work load and the overall inspection time of the site, which in turn pushed the cost-benefit-balance towards an advantageous configuration.

Building and extending the knowledge base

These briefly reported design case studies are examples of how one can analyze and design IT artifacts within complex organizational practices, and they also demonstrate the application of the principles of Grounded Design. To begin with, by investigating existing firefighting practices (according to section 'Pre-study/context study'), we saw that the firefighters' prevalent need in reconnaissance missions was not the mere determination of locations for spatial navigation. The more important requirement is rather the proper formation and communication of cognitive maps of the site with sufficiently rich context information as a shared reference system for navigation and coordination. The latter is not obvious and we were only able to disclose it through a sound ethnographic investigation based on participatory, and highly reflective, observation.

This insight has had a great impact on which technical functions to search for in design discourses with the practitioners (according to section 'Working on the artifact'). It became clear that automatically dropping artificial location tracking devices along the inspection paths, as developed and applied in previous attempts (Klann, 2009), was simply not sufficiently supportive for the firefighters to actively construct the mental and situated spatial picture of the site that they needed (Ramirez, 2012); it would instead appear more suitable to look for artificial devices that can be enriched by social and environmental context information in the course of the inspection process.

The second design case study provided further insights and findings regarding the practice in the field of first responders. By focusing on the practice of firefighting in the first line of intervention, it became apparent that the successful coordination of so-called 'groups' (fire engine crews) of firefighters as the smallest operational units is crucial for successful performance in reconnaissance missions in the early phases of fire incidents.

Meta-analysis: contributing to IS knowledge

A sound analysis of existing social practices, as we have shown, can orientate and inspire a creative design discourse about what promising prototypes might be tested in real use. The design case study approach, in turn, provides for a genuinely iterative strategy that identifies the mutually constitutive way in which technology and practice evolve together. Appropriating the prototypes for use is again a creative effort, the results of which are not predictable; and the proof of their usefulness and usability is in the emerging social practices

involving the artefacts in use. Reflecting on experiences with the new social practices using the IT artifacts – answering the question: how well does it work? – can serve as a fruitful source for creating further design ideas. Ethnographic observation of the design and appropriation processes and conceptual reconstruction of the whole design case, as outlined in this demonstrator example, finally delivers a set of design case studies to be integrated into an IS design knowledge base, as portrayed in Figure 2. In the context of the 'Landmarke' design case study, an innovative method of communication during indoor reconnaissance missions evolved from reflection and this led to a completely new set of features being added to the platform and thus also added to the 'value' of the existing system. The design and development of the communication support features led to a further design case study and consequently extended the knowledge base and allowed for comparative meta-studies.

The meta-analysis of the design case studies presented here reveals categories and 'structural configurations,' which contribute to the generation of more general scientific contributions.

The analysis of the relationship between the *autonomy* of the indoor firefighting teams and the *monitoring* commander outside the building revealed interesting insights (Denef *et al.*, 2011; Betz and Wulf, 2014). The impression of a strongly hierarchical paramilitary structure of order and obedience belies the fact that the commander outside the building substantially relies on the observations of the indoor working teams and that his decisions are strongly interwoven with the autonomous decisions of the teams indoors. This autonomy requires a synchronization of the operational picture.

Contrary to the naïve assumption that there is vast uncertainty in early incident phases, in-depth analysis of existing practices showed that there a considerable amount of disciplined routine when it comes to dealing with cases of emergency in practice. Thus actions, for example in typical fire incidents, turn out to be mainly predictable and therefore allow for anticipation and predefinition. It is these disciplines that in fact allow for improvisational action when needed. In general, conceptually incorporating the autonomy of working units in leading organizational structures is a key factor for designing useful and supportive IS artifacts for emergency response.

Discussion

Grounded Design is an IS DR approach established in the practice-theoretical tradition. In contrast to the design-centered perspective, it understands the design of IT artifacts as a multi-layer intervention in the social practices of an organization and builds on broad experience from action research. As compared to related research approaches, it copes better with problems of contingency and self-referentiality in IS development. It factors in the creative and abductive reasoning about artifact design and appropriation over time. With this understanding, it takes advantage of a broad body of theoretical insights into social practices both for understanding basic features like social inertia, resistance (or indeed dynamic capabilities) and for improving specific IS performance as well. It can further take advantage of and fit with well-established procedures such as participatory software development or evolutionary project management developed under the same broad practice-theoretical perspective. In particular, these insights can explain many of the frequent failures in IS design and help to orientate and inspire new IS design projects that avoid such difficulties.

Moreover, Grounded Design, as supported by this sort of practice-theoretical knowledge, allows for the building of an extensible IS design knowledge base by adding further design case studies, which conceptually reconstruct the social practices observed before, during, and after designing and appropriating the IT artifact. Such design case studies explain why certain design and appropriation achievements work under specific context conditions and contribute to design-relevant explanatory knowledge.

In order to make meaningful use of this type of design knowledge base in future IS design cases, it is necessary to acknowledge the inescapable fact that social practices in organizations differ widely across cases. Design and appropriation ideas and procedures that work in one social context need not necessarily be successful in another social context. Frequently, even the underlying problems of existing social practices are not obvious and often need to be disclosed by extensive observation and analysis. In this way, suitable measures to improve the efficiency of existing practices or to make use of knowledge from other cases can be envisaged. In this respect, the Grounded Design approach goes beyond ADR as proposed by Sein *et al.* (2012) as it avoids the specification of a typified problem class in early stages of the intervention.

Similarly, with its emphasis on evolutionary design and knowledge formation procedures, the Grounded Design approach is closely related to, and builds on, Multi-grounded Design (Goldkuhl and Lind, 2010) and Soft Design Science Methodology (Baskerville *et al.*, 2009). Where it differs is in the recognitions that the contingencies of creative design and appropriation processes mean that the transferability of design solutions cannot be assumed. The *a priori* determination of a class of artifacts offering solutions to a problem class is not straightforwardly achieved. Of course, existing knowledge feeds into research, but the transfer of knowledge must depend on analysis of both similarities and differences. The design case study approach that we have outlined offers a conceptual and empirical means to identify specific solutions to particular social practices in the light of existing knowledge. Based on detected similarities, such knowledge can guide new design efforts (cf. Wulf *et al.*, 2015).

There are, of course, severe limitations to the transferability of IS design knowledge; they are not, however, deficiencies in design knowledge *per se* but are rather – at least from the practice-theoretical perspective – a consequence of the contingency and self-referentiality of design interventions in social practices. Knowledge formulated in the form of design case studies, whose skilful and understanding application can inspire and guide new design and appropriation efforts on the basis of similarities being disclosed in the course of ethnographical observations or design discourses, is of clear value.

Furthermore, since the volume and relevance of interpretive IS research has increased markedly in recent years (Goles and Hirschheim, 2000; Walsham, 2006), it appears reasonable to perform cross-sectional investigations across a number of design case studies looking for context similarities or patterns and basic 'structural configurations' in the design and

appropriation processes in different contexts (Rodon and Sesé, 2008). Such similarities, patterns or structural configurations may constitute an *a posteriori* typification of IS design contexts and procedures.

With respect to putting more emphasis on IT in IS DR, another strand of future research should, we believe, look for more flexible and adaptable IT architectures and investigate how the use-oriented flexibility of IT artifacts can be expanded, thus rendering them more easily configurable and adaptable to different social practices. Achievements in this regard could considerably reduce IS design efforts.

Finally, as IS development projects still frequently fail to deliver sufficient benefits and newly developed IS often underperform, more research on IS performance problems is needed. Evidence from, and interpretation of, practical failures – drawing on precisely the kind of empirical and conceptual work we have outlined above – might be of as much relevance for IS development as straight forward DR.

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