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Infrastructuring and Participatory Design: Exploring infrastructural inversion as analytic, empirical and generative

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Abstract. The participatory design of CSCW systems increasingly embraces activities of reconfiguring the use of existing interconnected systems in addition to developing and implementing new. In this article, we refer to such activities of changing and improving collaboration through the means of existing information infrastructures as infrastructuring. We investigate a relational perspective on infrastructuring and provide an overview and a detailed account of a local infrastructuring process by tracing the concrete relations that emerged. The elusive quality of information infrastructures as being invisible is analyzed through the notion of infrastructural inversion. Infrastructural inversion is the gestalt switch of shifting attention from the activities invisibly supported by an infrastructure to the activities that enable the infrastructure to function and meet desired needs for collaborative support. Initially, infrastructural inversion was conceived as a conceptual-analytic notion, but recent research has also positioned it as an empirical-ethnographic and generative-designerly resource. In this study, we rely on all of these stances and contribute to the generative-designerly position. We explain the notion of infrastructural inversion and describe how it is distinct from the CSCW concept of articulation work. The context of the analysis includes a participatory design project that sought to reduce patients' fasting time prior to surgical operations by improving the interdepartmental coordination at a hospital. The project revealed the webs of relations and interdependencies in which fasting time is inscribed at the local level as well as regionally, nationally, and beyond. We pursue the relations, trace their connectedness across multiple scopes, and show how the process alternated between empirical and analytic activities of exploring relations and design-oriented activities of reaching closure. Our analysis shows that the notion of infrastructural inversion can enrich participatory design: Infrastructural inversion embraces the exploratory activities of tracing relations, while the design agenda drove the need for reaching closure. We conclude by discussing lessons learned for infrastructuring and for participatory design that engages with infrastructuring.

Keywords: Information infrastructure; Infrastructuring; infrastructural relations; infrastructural inversion; conceptual-analytic, empirical-ethnographic, and generative-designerly strategies; participatory design; effects-driven participatory design; collaborative design; healthcare.

1 Introduction

The starting point for this article is the ongoing discussions relating Participatory Design (PD) and CSCW, as introduced by Kensing and Blomberg (1998), along with the growing interest in 'Infrastructuring and Collaborative Design' discussed, among others, in the recent special issue of the CSCW journal (Pipek et al., 2017; Karasti et al., 2018). We approach infrastructuring as part of the design and use of information technologies, akin to the characterization: 'activities that contribute to the successful establishment of an information system usage (equivalent to a work infrastructure improvement)' (Pipek and Wulf, 2009, p. 447). PD literature also shows a growing interest in infrastructuring (Karasti, 2014) and various forms of end-user approaches to tailor infrastructures for local use (Bannon and Ehn, 2013). PD approaches to the ongoing reconfiguration of technologies-in-use have been referred to as 'continuing design in use' (Henderson and

Kyng, 1991), 'continuing design' (Karasti et al., 2010), 'design in use' and 'designing for design in use' (Bannon and Ehn, 2013), or as 'sustained PD' (Simonsen and Hertzum, 2012). We study a case from the healthcare sector and characterize infrastructuring as the activities that take place when cross-departmental and heterogeneous groups of clinicians strive to facilitate their collaboration by configuring, reconfiguring, developing, and establishing local guidelines and standards for effectively using the available technologies and information systems as part of their joint collaborative practice (Simonsen et at., 2015). Specifically, we highlight *the concrete relations that were traced and inverted during a healthcare infrastructuring process organized as a PD project, investigate the notion of infrastructural inversion, its analytic, empirical and generative potential, and discuss lessons learned for infrastructuring and PD.*

Complex phenomena such as information infrastructures 'do not just "unfold" or "emerge"; they are collective accomplishments which are refreshed in the shaping' (Neumann and Star, 1996, p. 236). Therefore, research on information infrastructures emphasizes that infrastructures are always *relational*, and because their development and use are defined by complex relationships, their evolution tends to take time and require negotiation. The question 'How to infrastructure?' started a *process*-oriented interest in infrastructures (Star and Bowker, 2002). In research on infrastructure formation and evolution, infrastructuring has become an increasingly popular notion (e.g. Hillgren et al., 2010; Bossen and Markussen, 2010; Clement et al., 2012; Le Dantec and DiSalvo, 2013; Karasti, 2014; Agid, 2016; Bødker et al., 2017; Ulriksen et al., 2017; Botero et al. 2019). In this article, we investigate how the relational and the processual meet in the concrete practices of infrastructuring. For this, we focus on one particular notion from the infrastructure vocabulary: infrastructural inversion.

The notion of infrastructural inversion has been proposed by Bowker (1994) as a gestalt switch of shifting attention from the activities invisibly supported by an infrastructure to the activities that enable the infrastructure to function. Infrastructural inversion has attracted increasing attention in research (e.g., Parmiggiani, 2015; Kaltenbrunner, 2015; Korn and Voida, 2015; Harvey et al., 2017). We use the notion to explore how participants in a PD project intertwined tracing and inverting infrastructural relations as they engaged in developing their work and its infrastructure support, that is, not only as research-related but also a design-oriented activity. While infrastructures tend to stay unnoticed and invisibly support activity, infrastructural inversion aims to bring the infrastructure to the foreground by 'learning to look closely at technologies and arrangements that, by design or by habit, tend to fade into the woodwork' (Bowker and Star, 1999, p. 34). Infrastructural inversion is a conceptually-based notion with methodological consequences. It has been recognized for its conceptual-analytic, empirical-ethnographic, and generative-designerly potentials (e.g. Bowker 1994; Bowker and Star, 1999; Jensen, 2014; Kaltenbrunner 2015; Parmiggiani 2015; Korn and Voida 2016; Harvey et al. 2017). Yet, its more concrete appearances and application in organized design processes remain underdeveloped. In this article we examine the interplay between the conceptual-analytic, empirical-ethnographic, and generative-designerly qualities of infrastructural inversion, and how they contribute to infrastructuring in an organized PD effort.

We investigate infrastructural inversion as a relevant notion for studying and designing information infrastructures. It attends to and helps in foregrounding the intrinsic *invisibility* of infrastructures, and it allows for uncovering and pursuing infrastructural *relations* and *connections* in the continuously emerging infrastructure. The notions of relational and invisible are by no means novel to the field of CSCW (e.g. Berg, 1999; Nardi and Engeström, 1999), though connectedness may be less familiar, due to the more small-scale and short-term emphasis of CSCW research (Monteiro et al., 2013; Blomberg and Karasti, 2013). Invisibility, in particular, is a widely acknowledged topic in CSCW. For instance, different kinds of invisible work have been identified (Nardi and Engeström, 1999; Star and Strauss, 1999) and critical aspects of collaborative work have been made visible through ethnographic workplace studies (Suchman, 1995; Schmidt, 2000; Blomberg and Karasti, 2013). Furthermore, invisibility has been successfully addressed in CSCW through two concepts, articulation work (Schmidt and Bannon, 1992; Star and Strauss 1999) and coordination mechanisms (Schmidt

and Simone 1996). In this article, we argue that in addition to them, the notion of infrastructural inversion has a place in CSCW and PD, particularly in studies of information infrastructure formation.

The design context of our empirical study concerns a PD project where the aim was to improve the coordination of surgical operations at a Danish hospital by focusing on fasting times. Multiple departments are involved in managing fasting times, and the aim of reducing the patient's fasting time could only be obtained by changing and improving the coordination among clinicians from all involved departments. In addition to coordination improvements, shorter preoperative fasting would reduce discomfort, frustration, and postoperative complications for the patients. Technologically, the project was to utilize a network of electronic whiteboards that had been recently introduced throughout the hospital. While fasting time appears a mundane and simple notion, we will show that it is a complex matter embedded in a web of infrastructural relations. Our analysis shows the multiple meanings of fasting time and the multiple considerations involved in reducing fasting times when several hospital units are to coordinate their activities. The project's scope reached across the units involved with surgery, many of its issues were hospital-wide, and also related in multiple ways and over multiple scopes with regional and national healthcare systems. We show how the project participants followed and inverted the relations, traced their connectedness, and describe how the design process alternated between activities for exploring relations and activities for reaching closure.

In the following we explain the conceptual background of infrastructural inversion and how infrastructural inversion is distinct from articulation work (Section 2), describe the method and setting of our empirical study (Section 3), and analyze selected workshops of the PD project that particularly focus on the issue of fasting-time (Section 4). We end by discussing lessons learned for infrastructuring and PD (Section 5).

2 Conceptual background

We conceptually draw from an information infrastructure notion initially put forward by Star and Ruhleder (Star and Ruhleder, 1994; 1996). The notion emphasizes *sociotechnical imbrication* in the sense that information infrastructure is always seen as a relationship between humans' organized ways of 'doing' things and the technologies that enable and support these practices. It is fundamentally grounded on a *situated and relational view* that infrastructure happens 'in practice, for someone, and when connected to some particular activity' (Star and Ruhleder, 1996, p. 112). The notion's relational quality makes it different from the views on information infrastructures as technical artifacts/objects (i.e., discrete, standalone entities) that are widely applied in engineering and design fields, and its situated nature differentiates it from those that focus on large-scale information infrastructures as macro-level systems, employed for instance in the Large Technical Systems field in the Science and Technology Studies (STS) tradition. It thus focuses on the 'when' of infrastructure, that is, highlighting that a functioning infrastructure is a fragile achievement in which multiple relations become aligned, rather than the 'what' of infrastructure, that is, providing a mapping of the components and operations comprising the infrastructure. In other words, the notion provides a challenge to the common 'technology artifact' view and puts information infrastructure forward as a contextualized, 'sustained relation'.

In their ensuing work, Star and Bowker (Star and Bowker, 2002) asked 'how to infrastructure', a question which has inspired research focusing on information infrastructure formation, often called 'infrastructuring' (e.g. Karasti and Baker, 2004; Karasti and Syrjänen, 2004; Ehn, 2008; Pipek and Wulf, 2009; Björgvinsson, Ehn, Hillgren, 2010, 2012; Le Dantec and DiSalvo, 2013). While there are different takes on infrastructuring, they are also similar in several ways. First of all, they share the above sociotechnical, situated and relational view of infrastructure. Second, they all direct attention to infrastructuring activities, broadening the focus and scope of design from mere technology to its embedding local context of practice, extending design towards ongoing, open-ended, long-term processes, and reintroducing politics into PD. Reading across these approaches reveals also complex relationships with the installed base. (Karasti, 2014)

In this article we recognize that while the notion of information infrastructure is fundamentally based on a relational ontology, infrastructuring brings along a process ontology (Karasti et al. 2018). Thus, the notion of infrastructuring integrates both relational and processual aspects of the studied phenomenon. Through our analysis we will show that the relational and the processual qualities are intertwined in how the participants of the PD project pursue certain aspects of fasting time. Therefore, in this section we describe the dimensions of infrastructuring that are most salient for the analysis (Star and Ruhleder, 1994, 1996; Karasti and Blomberg, 2018), namely invisibility, relationality and connectedness before elaborating the notion of infrastructural inversion. We suggest that the notion of infrastructural inversion can be used to address infrastructure's invisibilities by paying attention to them and foregrounding associated infrastructural relations and connectedness.

2.1 Invisibility of infrastructure

Star and colleagues emphasized the intrinsic invisibility of information infrastructures (Star and Ruhleder, 1994, 1996; Star 1999; Bowker and Star 1999). Recently, Larkin has drawn attention to how infrastructures inhabit a whole spectrum of in/visibilities, ranging 'from unseen to grand spectacles and everything in between' (Larkin 2013, p. 336). The point to be made here is that many infrastructures have both the spectacular and the invisible; the range from spectacular to invisible may also be within an infrastructure, and not only as a comparison between infrastructures. Even with the spectacular kinds or 'parts' of infrastructures designed for public display to elicit awe and admiration (Larkin, 2013), the less-impressive, unremarkable, mundane, unexciting, boring or tedious kinds/parts and processes of infrastructures exist across the range and remain out-of-sight, unseen, opaque or unknown (Bowker, 1994; Harvey et al., 2017; Karasti and Blomberg, 2018).

Short of the possible spectacular aspects, infrastructures are often seen as the 'substrate' that allows the 'substance' to happen. Infrastructures achieve their largest effects by being out of the way, sometimes deliberately hidden (Appadurai, 2014), or taken for granted which often happens once their use has been *learned as part of membership* in a community of practice (Star and Ruhleder, 1996). Good, usable infrastructures disappear almost by definition: 'the easier they are to use, the harder they are to see' (Bowker and Star, 1999, p. 33). When infrastructures work well, they 'just [are] there, ready-to-hand, completely transparent', they do not have to be reinvented each time, but invisibly support the task at hand (Star and Ruhleder, 1996, p. 112-113). This quality is akin to Heidegger's example of the hammer, highlighting the invisibility of tools in everyday use (Heidegger, 1962). Therefore, the users of the infrastructure are relatively unaware of it and how it works. The normally invisible quality of infrastructure *becomes visible upon breakdown* (Star and Ruhleder, 1996, p. 113), similarly to Heidegger's (Heidegger, 1962) notion of 'present-at-hand'. Infrastructures tend to fade into the background by both habit and design.

The invisibility of infrastructures is an outcome of considerable effort, work and investment (Bowker and Star 1999). In the same vein, it also takes a lot of work to uncover the invisible aspects inherent in an infrastructure. With infrastructures, according to Star, at issue is not an invisibility of a typical anthropological strangeness but rather 'an embedded strangeness, a second-order one, that of the forgotten, the background, the frozen in place' (Star 1999, p. 379). Therefore, extra measures, such as infrastructural inversion, may be needed to foreground the invisible.

In the hospital where the PD project was conducted, fasting time was an existing, taken-for-granted aspect of the everyday surgical work practices: the routine procedure was to check that each patient was on the safe side of the six-hour fasting time criterion to be able to undergo surgery. When the project attempted to make patients' fasting time visible on the whiteboards, many related, previously invisible issues were unearthed and addressed. This started with questions of the starting and ending time of fasting, of which especially the starting time had several invisible aspects, as we will demonstrate in Section 4.

2.2 Infrastructure as relational and connected

As already mentioned, infrastructures are fundamentally relational and emerge in situ in relation to organized practices where they are connected to particular activities. Infrastructures appear 'only as a relational property, not as a thing stripped of use' (Star and Ruhleder 1996, p. 113). The relational quality of infrastructure is further articulated in several of Star and Ruhleder's characteristics (ibid.): infrastructure is *embedded* in, or 'sunk into', other structures, social arrangements, and technologies; it is *learned as part of membership* and becomes taken-for-granted for members; it both shapes and is shaped by the *conventions of a community of practice*; it *builds on an installed base* and inherits strengths and limitations from that base.

Understanding the relational nature of infrastructure involves unfolding the technical, social, political, and ethical choices made throughout its design and development (Clarke and Star, 2008). In our example, as fasting time becomes the focus of attention, its taken-for-granted and surprisingly complex relations embedded in the work practices, procedures, conventions and sociotechnical installed base start to be gradually explored and unveiled in discussions.

As pointed out by Strathern, an inherent property of a 'relation' is that 'it requires other elements to complete it […] for the relation always summons entities other than itself' (Strathern 1995, p. 18). Thus, the very quality of 'relational' means being 'connected'. Aligned with this, is the connectedness of infrastructures where infrastructure 'has *reach or scope* beyond a single event or one-site practice, both temporally and spatially' (Star and Ruhleder 1996, p. 113). Infrastructure as a relational phenomenon is interdependent and inextricably connected with forming complex and extended socio-material-technical-political constellations. Harvey et al. (2017) see infrastructures as 'doubly relational' due to their simultaneous internal multiplicity and their connective capacities outwards. In the words of Star and Ruhleder, the internal multiplicity of an infrastructure links with the *installed base* and *conventions of the community of practice*, and through infrastructures' connective capacities outwards they plug 'into other tools and infrastructures' through the '*embodiment of standards'* (Star and Ruhleder 1996, p. 113).

Connectedness as a quality of a phenomenon brings together things of quite different scales (Strathern 1995, p. 19). Rather than employing the rather straightforward and quantifying approach of 'scaling up' in terms of increasing numbers of collaborators, size of data, and availability of computing cycles, or broader geographical reach often used in technology oriented discussions as pointed out by Ribes and Lee (2010), we consider the *reach or scope* of infrastructures' connectedness more qualitatively as evoking understandings of the scopes and boundaries of infrastructures as open-ended (Edwards, 2007) or unbounded (Hine, 2009), never given but always contingent (Jensen and Winthereik 2013). In our study, the participants followed the relations of fasting time to multiple scopes and unearthed connections across organizational and institutional boundaries, for instance, to their patient population, other hospitals, regional standards, and the Danish accreditation system.

2.3 Infrastructural inversion

Infrastructural inversion was initially introduced by Bowker (1994) to address the propensity of infrastructures to remain invisible backdrops to social action. The notion can be understood as struggling against the tendency of infrastructure to disappear by operating as a gestalt switch, a figure-ground reversal. Bowker illustrates the reversal through an example of life expectancy in the nineteenth century where the material infrastructures are brought from the background to the foreground of attention. In a nutshell, the point is that while it was generally thought that advances in life expectancy were due to improved scientific knowledge, the major causes, according to Bowker, actually related to changes in systems of food production and consumption, and to improved sewage systems (Bowker 1994, p. 235). Infrastructural inversion, in Bowker's example, thus draws attention to the material interdependent systems/infrastructures contributing to life expectancy.

In addition to high-level societal figure-ground reversals, infrastructural inversion has been also used to shift attention to the mundane operational processes, i.e. the silent, unnoticed work that *enables* infrastructures to function rather than the work that infrastructures invisibly support (Bowker, 1994; Star and Ruhleder, 1994, 1996). Furthermore, infrastructural inversion has been used to direct attention to the 'singularly unexciting' things, such as unremarkable lists, commonplace plugs, technical specifications, standards, bureaucratic forms, and details buried in inaccessible code, as well as to hidden mechanisms subtending the more visible processes (Star, 1999).

Our example of the fasting time starts out as the infrastructural inversion of a 'singularly unexciting' thing and – as the activities in the workshops start to reveal the multiple relations connected over multiple organizational boundaries of fasting time – grows into carrying out infrastructural inversion of the related practices at the wards, patients, and standards and requirements on clinical work by various healthcare institutions. Our case allows for recognizing the rich interdependent relations of the technical, social, organizational, and institutional constituents, the relations and connections that need to be inversed to understand the infrastructural embeddedness and outward connectedness of fasting time.

Initially infrastructural inversion was used by the researcher as a *conceptual-analytic* strategy to bring to light infrastructural invisibilities. It has proved particularly useful for studying mature, well-working infrastructures where analysts are able to foreground and scrutinize the hidden relations of mundane materialities and operational processes that produce the smooth flows and circulation of the infrastructure (Bowker, 1994; Star and Ruhleder, 1994, 1996). More recently additional methodological takes on the notion have been forwarded, such as *empirical-ethnographic* and *generative* strategies. Those who propose infrastructural inversion as an *empirical-ethnographic* strategy see that some situations, such as disruptions, disturbances, and breakdowns, 'elicit *naturally occurring inversions* in which various exigencies make infrastructural operations abundantly visible to some people' (Harvey et al., 2017, p. 4, original italics). Though breakdowns were already recognized as a useful entry point also in the conceptual-analytic strategy, here the point is that inversion is an empirical condition for the people working with the infrastructure *before* it becomes an analytic tool for the researcher (Jensen, 2014; Harvey et al., 2017). For both researchers and people working with infrastructures, moments of breakdown are opportune situations because 'entire swaths of infrastructural activity (even those that didn't fail such as properly functioning back-ups or routinized repair activities) are revealed' (Ribes and Lee, 2010, p. 238). Breakdowns have become a frequently used entry point for infrastructural inversion in studies where the fragility of infrastructures has been more apparent than routine, smooth connectivity. For example, Bossen and Markussen (2010) analyzed the breakdown of an electronic medication module upgrade. The breakdown created an inversion that brought to the fore – for the researchers to study – the work that actors and artifacts did to achieve stable enough cooperative arrangements. The study thus illustrates that the empirical-ethnographic approach by the hospital personnel and the conceptual-analytic approach by the researchers were carried out side-by-side due to the unexpected breakdown.

Moving away from breakdowns, another entry point for using infrastructural inversion as an *empirical-ethnographic* strategy is to turn to the members who are already involved in infrastructuring activities as part of their job descriptions – whether as part of planning, designing, maintaining or repairing infrastructures (Kaltenbrunner 2015; Dagiral and Peerbaye 2016; Parmiggiani et al., 2015; Parmiggiani and Monteiro 2016). In a study of infrastructure development in an oil and gas company, Parmiggiani (2015) identified a subset of actors who, as part of their daily work, engaged in infrastructural inversion to align the evolving environmental monitoring infrastructure with the installed base of tools, work practices, and professional responsibilities. By following her 'infrastructural allies', Parmiggiani was able to uncover significant infrastructural activities in support of the emerging infrastructure. She realized that she and her allies were interested in answering the same kinds of questions and that they all used infrastructural inversion as a resource.

Yet another infrastructural inversion strategy positions it as a generative resource on which actors themselves draw in developing their infrastructure. While some recent scholarship has pointed in this direction (e.g. Edwards 2010; Mayernik et al. 2013; Parmiggiani 2015), Kaltenbrunner (2015) has specifically explored the generative potential of infrastructural inversion. He has studied how digital humanists engage in defamiliarizing their socio-material research infrastructure to expose the invisible workings of knowledge production in their fields. They use infrastructural inversion as a generative resource for imagining new ways of digital scholarship and for creating ways to engage with them. The digital humanists 'reinterpret the status quo of infrastructure in light of potentialities, thus paving the way for embedding new tools in particular ways' (Kaltenbrunner, 2015, p. 19). Pressing further on the generative dimension of infrastructural inversion, Korn and Voida (2015) make a specific connection between infrastructural inversion and design. Their study brings together contestational design and infrastructures of civic engagement, in which friction can be thought of as a 'designerly enactment of infrastructural inversion' (Korn and Voida, 2015, p. 154). Korn and Voida conclude by suggesting to 'reposition infrastructural inversion as an approach to design rather than as ethnographic practice' (ibid., p. 154).

In summary, while the conceptual-analytic strategy was intended for the analytic purposes of the researcher, the empirical-ethnographic strategy, by starting to bridge the distinction between the conceptual and the empirical, expanded to include also users of the infrastructure as avid inverters, and finally the generative-designerly strategy starts with the performativity of infrastructuring but also seeks to put this insight to use in an explicitly generative way (see, e.g., Marres et al. 2018 speak about a move to 'inventing' the social).

2.4 Juxtaposing 'Articulation Work' and 'Infrastructural Inversion'

Both articulation work and infrastructural inversion are notions aimed at unearthing the invisible. The former is one of the key notions for the CSCW field, the latter is likely less familiar. Therefore, we conclude our conceptual background by juxtaposing these notions, in order to reflect on how infrastructural inversion is particularly suitable in the contexts of infrastructuring.

Drawing on the work by Strauss (1985, 1988), articulation work is described in CSCW as: 'work that gets things back 'on track' in the face of the unexpected, and modifies action to accommodate unanticipated contingencies' (Star and Strauss 1999, p. 10). Schmidt and Bannon (1992) further specify that the fundamental role of articulation work in cooperative activities is to manage the distributed, yet interdependent nature of work that follows from the division of labor in the workplace where it is important to coordinate the workers' individual activities. Articulation work is 'extraneous to the activities that contribute directly to fashioning the product or service' (Schmidt and Bannon 1992, p. 8). Getting 'things back "on track"' thus refers to the work required to be able to continue with the production work. If considered in the context of infrastructures, the amalgamation of production work and articulation work is comparable to the 'work that infrastructures invisibly support' rather than the 'work that enables infrastructures to function', and it is the latter 'mundane operations' which Bowker wishes to bring to the fore with the notion of infrastructural inversion as we have explained in Section 2.3.

Furthermore, in CSCW articulation work is seen as fundamental to all work. The need for articulation work arises from the innate under-specification of situated action through formal organizational schemes (Suchman, 1995). 'It is impossible […] to anticipate and provide for every contingency which might arise in carrying out a series of tasks. No formal description of a system (or plan for its work) can thus be complete' (Gerson and Star 1986, p. 266). In order to 'get things back on track', 'the variations, deviations and inconsistencies must be resolved in the "here and now" through the actions of workers' (Blomberg and Karasti 2013, p. 379). Articulation work thus designates the situated activity of coordinating and managing cooperative work processes in and for the 'here and now', immediate action so that ongoing collaborative work can get done. In contrast, the notion of infrastructural inversion encompasses and emphasizes also going beyond the 'here and now' – temporally, spatially, organizationally – to uncover more extensively the multi-faceted relationally embedded and connected phenomenon of infrastructuring. In different words, the

notion of articulation work has been used in CSCW to analyze and understand work in situated work settings, whereas the notion of infrastructural inversion – developed in the context of studying infrastructures – attends to extended infrastructural scopes as we will illustrate through our empirical findings in Section 4.

Much of articulation work is implicit (Strauss 1988) and therefore those who perform it as part and parcel of their work activities may be unaware of it and may have difficulties describing the articulation work involved in their work. Simply asking people about their work or the work of others does not necessarily reveal the articulation work needed to get things done, therefore, ethnographic workplace studies have been instrumental in providing in-depth analyses to reveal the underspecified and sometimes unstated characteristics of articulation work (Blomberg and Karasti 2013). This imparts the idea that it requires an outside observer to be able to uncover the implicit, underspecified and unspoken of articulation work. In CSCW, the notion of articulation work has stayed in the hands of the analyst, and it has remained an analytic concept.

The notion of infrastructural inversion was also initially created and launched as an analytic concept to be used by the researcher (Bowker, 1994). As Harvey et al. describe, '*analysts* were able to bring to light the hidden relations on which smooth circulation depended' (2017, p. 3). An analytic approach to infrastructural inversion was and is particularly relevant in contexts where infrastructures work well and 'smooth flow' can be expected. Over time the original *conceptual-analytic* notion of infrastructural inversion has taken on new guises further distinguishing it from articulation work. Harvey et al. point to *empirical-ethnographic* inversions where 'some situations elicit *naturally occurring inversions* in which various exigencies make infrastructural operations abundantly visible to some people' (Harvey et al., 2017, p. 4). In situations where the relations that working infrastructures depend on are revealed to the involved people through some kind of breakdown, 'inversion is an empirical condition *before* becoming an analytical tool' (ibid., p. 4-5). The third variation of the infrastructural inversion refers to the *generative-designerly* strategy based on the work by Kaltenbrunner (2015) and Korn and Voida (2015). The condition more descriptive of the generative-designerly form of infrastructural inversion is that the people engaged in inverting aspects of their infrastructural work settings *were concerned with generating change*. Thus, infrastructural inversion can also be interpreted as a *generative* resource actors themselves draw on in developing infrastructure (Kaltenbrunner, 2015), allowing for a *designerly* enactment of infrastructural inversion (Korn and Voida, 2015).

Our aim is not to criticize the notion of articulation work, it – obviously – remains a key concept in CSCW as well as in the study of infrastructures and infrastructuring. We strongly align with Star's argument: 'Only by describing *both* the production task and the hidden tasks of articulation, together and recursively, can we come up with a good analysis' (Star, 1999, p. 387). Our argument is that the notion of infrastructural inversion is also needed, because it is created and fitting for dealing with the kinds of invisibilities that are inherent in infrastructures and infrastructuring. The notion can be used to foreground infrastructural invisibilities and it attends to the extended infrastructural scopes. Furthermore, it can take multiple forms that bridge the distinction between the conceptual-analytic, empirical-ethnographic, and generative-designerly. This is a crucial point for infrastructuring which does not rely on the commonly accepted, differentiated roles of user-participants and designers but is based on an idea of inclusiveness in participation in infrastructuring, intentionally blurring the accustomed role boundaries in design (Karasti et al. 2018). Infrastructural inversion enables us to foreground normally invisible relations of work and, in our case of fasting time, the details of how fasting time is managed and shapes work become more legible through this notion, in part due to the paired effects of analytic-conceptual, empirical-ethnographic and generative-designerly frames. This is in contrast to the kinds of foci we might have had through the notion of articulation work.

In this article, we explore further the theme of integrating infrastructural inversion with design in a project involving healthcare professionals who engage in infrastructuring work while facilitated by PD researchers. However, the use of breakdowns (Clement et al. 2012) or frictions (Korn and Voida 2015) as entry points for

infrastructural inversion in design was not feasible in this project because purposefully introduced disruptions or disturbances could have incurred risks to patients, and breakdowns would not occur naturally because the infrastructure in focus, i.e. the networked whiteboards, was not yet in use for the kind of interdepartmental coordination that was the topic of the project. Instead, the PD activities in our study enabled a space for infrastructural inversion to unfold. Our study is an example of healthcare professionals engaging in infrastructural inversion of the *empirical-ethnographic* and *analytic-conceptual* kind, and on this basis, together with PD researchers, bootstrapping to more *generative-designerly* infrastructural inversion. The project could be described as building in time and space for the participants to engage in tracing and inverting infrastructural relations, while at the same time keeping to an intentional change agenda coupled with design. This suggests the bridging of the distinctions between the analytic-conceptual, empirical-ethnographic and the generative-designerly takes on infrastructural inversion in infrastructuring.

3 Empirical setting and methods

In this section, we first introduce the empirical setting of the hospital where a transition was ongoing from traditional to electronic whiteboards. Then we describe the effects-driven PD approach and the project that applied the approach in order to expand the use of the new whiteboards for interdepartmental coordination of work. Last, we describe the retrospective analysis through which we focused on how the project participants engaged in tracing and inverting aspects of fasting time, an issue that had been collaboratively identified as key for improving the coordination of surgeries among the medical units.

3.1 The hospital and its networked electronic whiteboards

The PD project that is analyzed in this article was conducted at a medium-sized hospital with 250 beds and 1,140 employees, serving an area of approximately 150,000 citizens, in Region Zealand, Denmark. The project was approved by the healthcare region and by hospital management and organized in collaboration between two of the authors, Region Zealand, and the electronic-whiteboard vendor. It was one activity in a longitudinal collaboration of the two authors with Region Zealand focused on the use of electronic whiteboards at the hospitals in the region (Hertzum and Simonsen, 2015; 2016; 2019). In 2009 this hospital had introduced electronic whiteboards in the emergency department and started, in collaboration with the whiteboard vendor, a process of evolving the whiteboard technology into a mature product (Rasmussen et al., 2010). The whiteboard had been successfully implemented in the emergency department and on that basis networked electronic whiteboards were introduced on all departments in the hospital in December 2012.

The idea with the electronic whiteboards is to replace the traditional dry-erase whiteboards common at all hospitals. Dry-erase whiteboards contain mainly logistic information about the patients in the department, i.e. they support intradepartmental coordination. Replacing dry-erase whiteboards with networked electronic whiteboards opens the potential for re-purposing the whiteboards to support also interdepartmental coordination, to include access to clinical information from other systems, such as laboratory systems, and to be accessible from different platforms, i.e. large touch-screens, computers, tablets, etc. (Lassen and Simonsen, 2014). Large, wall-mounted displays (Figure 1) on all departments provided permanent access to the network of whiteboards, which in addition could be accessed through any computer. The whiteboards gave one row of information for each patient. The patient information fields were configurable and tailored to the needs of the individual departments. Frequent fields of information included, for example, time of arrival, patient name, room, responsible physician, and the status of laboratory tests. An early example of information for interdepartmental coordination was a field labeled ‘next stop’, which specified the department to which the patient was scheduled for transfer.

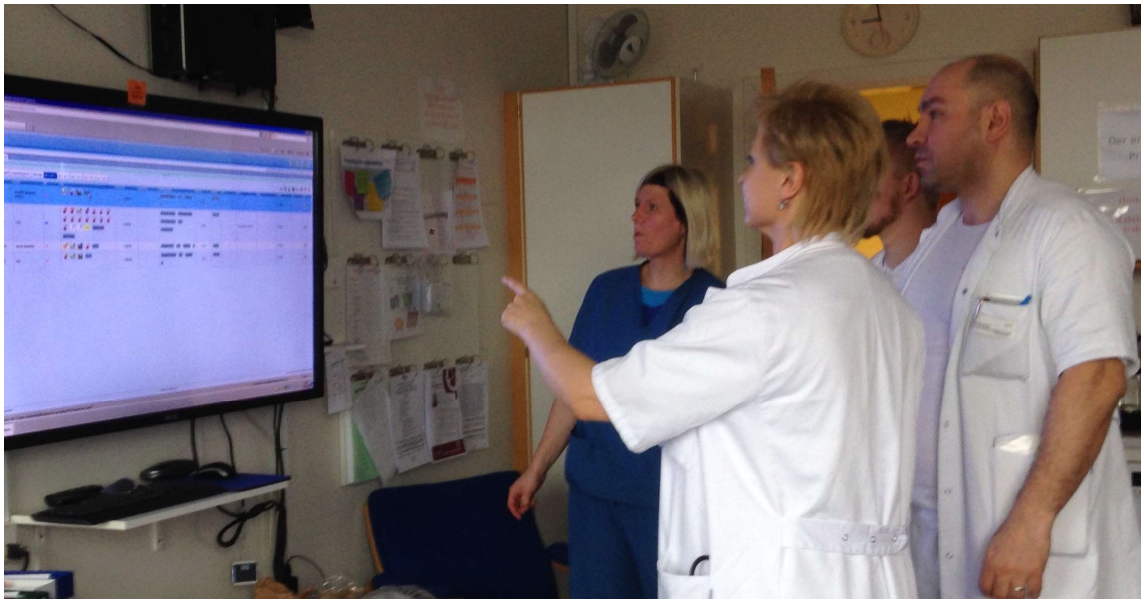

Figure 1. The electronic whiteboard at the operating ward.

3.2 The effects-driven PD project

The PD project conducted by two of the authors and a group of clinicians at the hospital focused on the use of the networked electronic whiteboards for improving the interdepartmental coordination of operations. The project followed the effects-driven PD approach described by Hertzum and Simonsen (2011). Effects-driven PD focuses on the effects (i.e., the specific and preferably measurable outcomes related to technology use) that the users would like to obtain through their adoption and use of a specific information technology. The approach consists of three overall activities as outlined in Figure 2: the specification of desired effects by local clinicians in relation to using available technologies; the realization of these effects through local experimentation and intervention; and the formative evaluation and assessment of whether the effects are achieved.

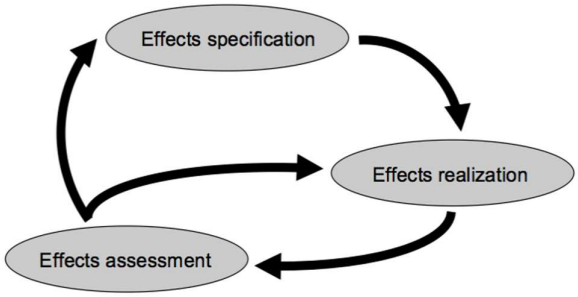

Figure 2. Overall activities of effects-driven participatory design (Hertzum and Simonsen, 2011a, p. 6).

The entire PD project spanned one and a half years, from September 2014 until December 2015. The primary empirical activities were four initial workshops in the fall of 2014 (a total of 10 hours) forming the effects specification activity; followed by eight meetings (a total of 16 hours) in the spring of 2015 constituting a first instance of effects realization; three meetings (a total of 7 hours) in June and September 2015 with effects assessment; and finally, five meetings (a total of 12 hours) during the fall of 2015 forming a second instance of effects realization. In the analysis we will focus only on the first instance of effects realization.

The project started with effects specification workshops in which we first introduced the effects-driven approach and then worked with the clinicians to specify desired effects to be pursued in the project. Clinicians from different departments and different staff groups were invited. While some clinicians participated in several workshops, some others participated in only one. The documentation of the workshops was the evolving description of the effects. At the first two workshops the effects brought up by the clinicians were recorded on flip-chart sheets, which were annotated and elaborated as the discussion of the effects progressed. After the third workshop, we converted the flip-chart sheets into a document with a page for each effect and we structured the specification of the effects to facilitate prioritization and bring out information still missing in the specifications (see Figure 3 for both the template for each specification and how it was filled in for the chosen effect of 'shorter fasting time'). The document provided the input for the fourth workshop at which the clinicians prioritized the effects. In total nine effects had been specified and the effect of reducing the patients' preoperative fasting time received top priority, because long fasting times are a concrete, well known, and common problem that is generally acknowledged among clinicians and directly related to the quality of patient treatment.

Effect: Shorter fasting time (in excess of the required 6 hours) Priority: high
Description: Patients must fast for 6 hours before operation. But the fasting time is, in practice, longer if the operation for example must be postponed. The period of fasting negatively impacts the patient and the patient's health. It is therefore an important effect in relation to the transfer of patients for operation that patients fast as little as possible in excess of the 6 required hours.
Measurement of effect / Requirement to electronic whiteboard: To be able to determine the fasting time we need to know when it starts and ends. *Starting time*: Is it already recorded on the whiteboard when the patients start fasting? Otherwise, it must be recorded somewhere else? *End time* (i.e., the time of operation): Is recorded on the whiteboard. Correct? In addition to the recording of the start and end times of each operation we need a daily calculation of the average fasting time (this involves combining data from the whiteboards of different departments).
Plan to obtain effect:
Person responsible for intervention:
Current status:
Barriers:
Stakeholders:

Figure 3. The sheet specifying the fasting-time effect from the effects specification workshops; the not yet specified parts indicated subsequent work tasks necessary to realize the effect.

Fasting is mandatory before operations to minimize vomiting during anesthesia and, thereby, reduce the risk of pulmonary aspiration. Clinical practice guidelines recommend that patients abstain from food for six hours before surgery (American Society of Anesthesiologists, 2011). However, patients are often fasting for considerably more than six hours, partly because older guidelines recommended fasting from midnight the day before surgery – a practice that has proven slow to change (Maltby, 2006). The nurses on the studied hospital experienced almost on a daily basis that patients were frustrated because they had been fasting for 10, 12, or 15 hours and still did not know when they would undergo surgery. In addition, emerging evidence shows that the consequences of prolonged fasting are not restricted to patient discomfort, hunger, and thirst but also include increased insulin resistance, loss of body mass, reduced muscle strength, and delayed recovery (e.g., Lambert and Carey, 2015; Nygren, 2006; Pimenta and Aguilar-Nascimento, 2014). Thus, fasting

times closer to the recommended six hours are likely to reduce postoperative complications and shorten patients' hospital stay. Reducing the fasting period requires an improvement in the interdepartmental coordination of the operations, thereby providing a match with the project's overall aim to improve collaboration by utilizing the networked whiteboard infrastructure. In the following we will – for the sake of brevity – call the 'effect of shorter fasting time' just 'fasting time'.

During the above outlined effects-specification workshops we were merely able to appreciate that the fasting-time effect seemed to capture the entire coordination of operations and take a first small step in understanding the issues and interrelations brought to the fore by assigning primacy to fasting time. It was only subsequently and gradually – over the next several months – that the entanglements of the coordination of operations were unveiled, as will be described in Section 4.

After the effects-specification workshops a small group was established to realize the fasting-time effect. The hospital had an organization of 'super users', i.e. local clinical staff responsible for the electronic whiteboards, with one or two nominated representatives from each department. Three super users (a nurse from the operating ward and a secretary from each of the two surgical departments), a research assistant (a former nurse from the surgical department) and two of the authors of this article formed the group to continue the work. The group gathered regularly (approximately once every two weeks) for meetings during which the steps in realizing the fasting-time effect were identified, clarified, delegated, and followed-up on. While we – the researchers – set the agenda for the meetings and chaired the discussions, the three super users provided most of the content of the discussions (Hertzum and Simonsen, 2019).

With the permission of all group members and other participating clinicians, the meetings were audio-recorded. Based on the recordings, the research assistant produced written minutes, which were circulated among all meeting participants for comments and approval. The activities performed in-between the meetings, by us as well as by the super users, were reported and discussed at the meetings. Thereby, the documentation of the meetings also contained a record of these activities. In addition to the written minutes, nine of the meetings (including the meetings analyzed in Section 4) were transcribed because the discussions at these meetings were particularly important to our analysis.

As a supplementary source of data, the research assistant made observations at the operating ward (i.e., the ward at which the operations were performed) and the two surgical departments (i.e., the departments for patients scheduled for an operation). These observations were documented in field notes that were used as input for the meetings. The research assistant had previously been employed as a nurse at the studied hospital, therefore she had both the professional background to understand the observed activities and the personal background to make observations at the departments without being a stranger. When observations were conducted, this was made explicit to the clinicians and they had the opportunity to terminate the observations at any time. The observations served to get a sense of how operations were coordinated: how fasting times were recorded and used in the surgical departments in existing practice.

3.3 The retrospective analysis

This article is based on a retrospective analysis we (the three authors) conducted on the effects-driven PD project. We started with a narrative approach through which the first and third authors, who had participated in the project, described and explained it to the second author, who was new to the project. We gradually refined our focus as the infrastructuring qualities of the project started to be articulated. We analyzed the empirical material through a collaborative process of repeated, in-depth sessions. Our discussions alternated between questions about what had happened, asked from the point of view of an interested but not empirically engaged analyst, and descriptions of and reflections on events and courses of related events. We also intensively worked with the documentation of the empirical activities and used our experience from having participated in the activities. We aimed for an analysis that was informed by our concrete involvement

in the project but, at the same time, maintained a balance between this involvement, a retrospective, analytic viewpoint, and a conceptual interest that emerged during the analysis process.

We began our discussion of the project process with a general interest in infrastructuring. Our repeated discussions were performed in four steps. First, we established a timeline of the events that made up the project. Subsequently, other activities, decisions, and observations were added. Second, we walked through the timeline of events to describe, elaborate upon, and discuss them. In these discussions, several conceptual options were explored, and gradually we became convinced that the notion of infrastructural inversion would be of interest and relevance in conceptualizing the empirical findings. This walkthrough provided an overview of the entire fasting-time project, and we began to identify events of particular interest to our analysis. Third, we focused more selectively on the events in which aspects of the clinicians' understandings of the coordination of operations and, more specifically, their understandings of fasting was articulated. We tentatively started to relate these events and participants' activities and interactions with the notion of infrastructural inversion. This happened in particular for the meetings analyzed in Section 4. Fourth, we conducted detailed analyses of the infrastructural relations and connections invoked in association with the rich sets of fasting-time related issues voiced by the meeting participants. These issues revealed hidden relations and mechanisms subtending the more visible processes. Star (1999) referred to this kind of infrastructural inversion as attending to the 'singularly unexciting', mundane details. We drew figures (two of which are presented in Section 4) to bring together the relational details and illustrate their connectedness over varied scopes.

4 Results: Tracing, inverting and designing for infrastructural relations across multiple scopes

In the following, we provide an account of unfolding discussions and issues during a local infrastructuring process. We focus on three meetings that are particularly interesting from the point of view of infrastructural inversion. The meetings concentrated on defining fasting time and when fasting begins (two consecutive meetings held in February and early March, 2015; presented in Section 4.1) and developing a standard procedure for documenting fasting and fasting start-time (a meeting held in late March, 2015; Section 4.2). We describe how the participants traced and inverted relations by pursuing the topic of fasting time and opening for reflection on emergent issues and concerns, which then find closure in designerly formulations and, in turn, subsequently lead to tracing and inverting other relations and their connections. The quotes are based on the transcriptions of the audio-recorded meetings. They are presented in a 'readable' writing-style English, however carefully respecting the meaning of the original utterances in Danish.

Figures 4 and 5 provide a schematic overview of the issues discussed in the meetings. Our aim with the figures is to highlight the *concretely traced relations*, the *varied scopes* of these relations and connections, and make a distinction between issues/relations that represented *existing practices* (shown in normal font in the figures) and those that envisioned relations of *future practices* (shown in italics). The figures are chronologically ordered (top-down) to show how one issue raised and investigated opens to another one. Variations in the scope/reach of relations' connectedness are indicated by horizontal distance from the node (on the left side of the figures) depicting the focal theme of the discussion. Closest to the node we find a mixture of work-practice issues and concerns including envisioned future practices in local work contexts. Half way out to the right, we locate issues related to the hospital as a whole, pertaining, for example, to the project itself, conformance with regional requirements, and available technological options. Furthest to the right we find more 'global' issues, including a regional or national level: The project contributed to these levels that also formed conditions with which the project's change agenda had to be aligned.

4.1 Defining fasting time and when fasting begins

This section describes the unfolding discussions and reflections tracing, inverting and exploring different relations during the process of defining fasting time and when a patient's fast begins (Figure 4). We met twice

with our group of super users to address how fasting time should be measured. To remind the reader, the management of fasting times was a standard operating procedure, which gained its invisibility from being routine, taken-for-granted, and embedded in the existing clinical practice. Fasting was an everyday concern visualized by a checkmark for each patient before operation, thereby indicating that the patient had abstained from food for the required six hours prior to the operation. The standard procedure included letters informing elective patients to fast before arriving at the hospital and a question posed by the anesthesiologist as part of the pre-operational procedure.

Our meeting started by reviewing the fasting-time effect specification sheet from the project's initial effects specification workshops (Figure 3). At the prior effects-specification workshops, it had been anticipated that measuring the fasting time was relatively straightforward and could be done by extracting existing data from the electronic whiteboard. This turned out to be the case only for the end-time of fasting, which was available as the start time of the patient's operation. Discussing the information available on the whiteboards clarified that the whiteboard contained no data specifically indicating the start of the fasting period (Figure 4). This triggered reflections on how fasting times were actually recorded at the wards. Fasting start-time was sometimes recorded in the nursing record, but this was in another system and in a free-text field from which the data could not be automatically extracted. This insight moved the reflections towards how the whiteboard could be used to record the fasting start-time. If both the start-time and the end-time for a fast could be extracted from the whiteboard, this would constitute the required fasting-time measurement, and the discussion could reach closure. The discussion illustrates how the concept of fasting time ties into the installed base of technologies-in-use, including the traditional whiteboards and the nursing record system, as well as the established practices of how the nurses record fasting times using these technologies. The installed base intertwines with the history of dry-erase whiteboards, originally only used for temporary information supporting the coordination between the clinicians on duty on each ward, and the use of a nursing record system for the mandatory documentation of patient care.

The question of how to record the fasting start-time on the whiteboard(s) opened the discussion for reflections on the current practices for managing fasting time at the hospital and revealed the important distinction between acute and elective patients. Acute patients are those for whom the decision to operate is made during their hospital stay. In contrast, elective patients are scheduled for planned surgery and are informed by letter to begin fasting at midnight the day before they are to arrive at the hospital for their surgery. *'We write to the elective patients, "You must fast from midnight the day before," and then they all arrive at the same time in the morning'* (Super User 1). *'All our electives who arrive as scheduled are handled as if they have been fasting since midnight'* (Super User 2).

Tracing the practice of managing fasting for elective-surgery patients revealed another important distinction between two logically different ways of understanding the start of fasting: 'prescribed' and 'real fasting start'. 'Prescribed fasting start' denotes the time from which the elective patient is requested to begin fasting. 'Real fasting start' is the time from which the patient actually stops eating before surgery, whether elective or acute. This distinction became the center of the discussion as there is often a significant difference between the prescribed and the real fasting start-time. Commonly, elective patients managed their prescribed fast as follows:

> *"There are many patients who fast much longer than necessary by their own choice because they have been trained to do so: "I am going to have an operation, so I cannot eat or drink. Well, she told me I could, but I won't do it anyway." I can remember from the outpatient clinic that many patients came and told us, "Well, you said that I could eat breakfast, but I didn't because in the old days you had to fast longer, and my fasting should not be a reason for not being operated." They are trained that fasting means "nothing at all" and "better too much fasting than too little"'* (Super User 3).

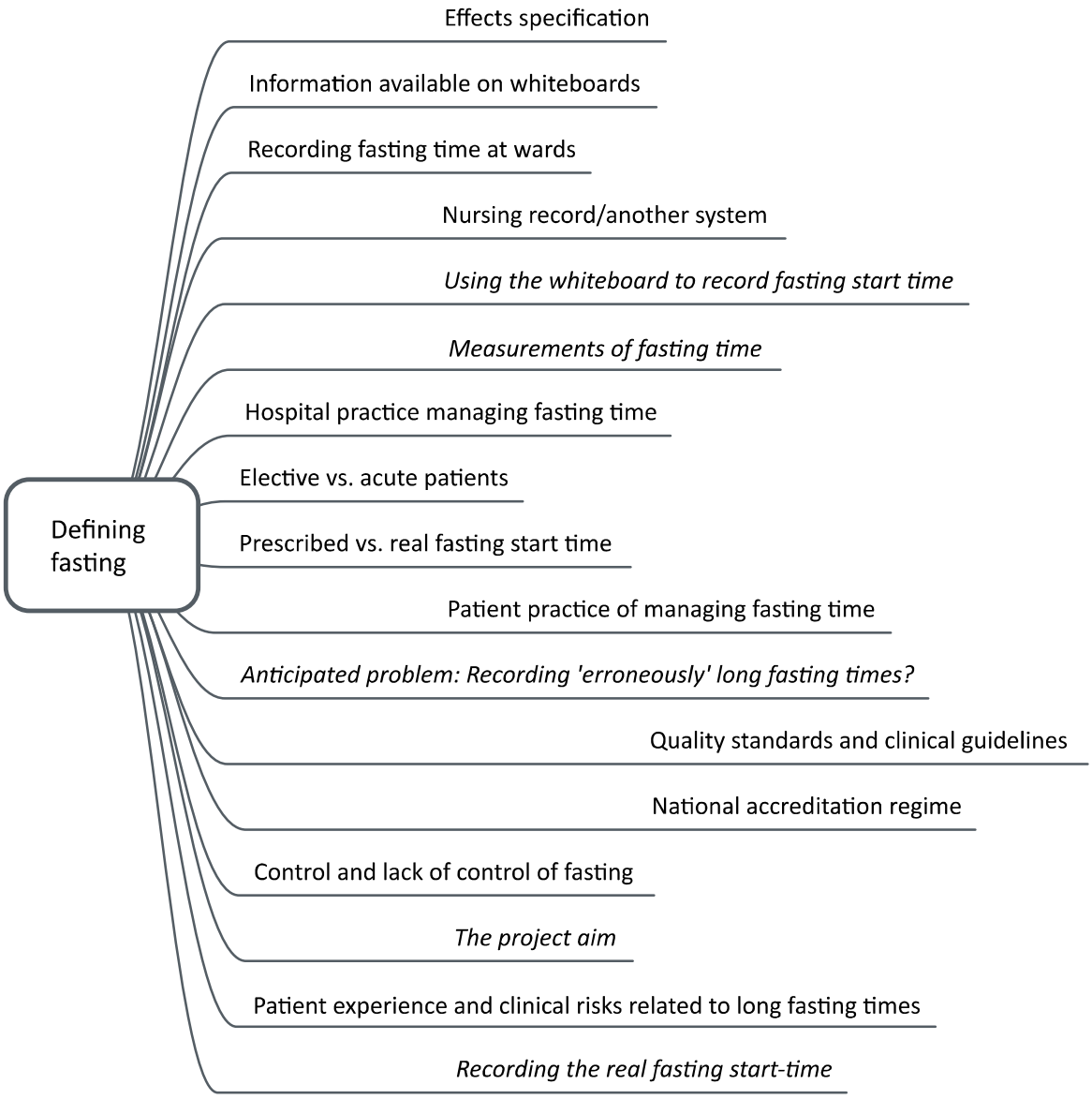

Figure 4. Relations traced, inverted and designed for in the process of defining fasting time during the two meetings in February and early March, 2015.

The difference between prescribed and real fasting start-time led the super users to voice concerns about how to deal with this issue. One super user raised the concern that basing measurements of the real fasting time could create a perception of low quality in the patient treatment: '*I wonder if using the whiteboards to record actual fasting start-time will provide an "erroneous" picture of having far too many patients that are fasting much longer than necessary*' (Super User 3). Concerns were also raised about who could potentially be blamed if the data were interpreted as indicating low quality:

> *'When a patient chooses not to eat breakfast because they did not feel like it and then arrives for a checkup at the outpatient clinic then, somehow, I believe it is "cheating" to record 6:00 p.m. as the fasting start. We might receive the patient at 10:00 a.m. and decide to operate at 6.00 p.m. which would result in a 24-hour fasting time. The decision to operate is made at 10:00 a.m. and specifies the*

time to begin fasting. We should measure according to this time. It's not our fault that the patient did not eat beforehand' (Super User 2).

This concern expanded the scope of the discussion to include the Danish national accreditation regime, against which hospitals and their staff are frequently audited to assess how clinical processes comply with local clinical guidelines and national quality standards (Simonsen et al., 2018).

The discussions about how to record fasting start time were shaped by the conventions of this community of practice and the standards embodied in clinical guidelines. As indicated in Figure 4 by the relations' relative distance to the node, the scopes of the issues discussed comprise the local hospital practices but also reach into the patients' private life, by including their views regarding when to stop eating. Furthermore, the scopes extend to the national accreditation system and its quality standards: while the hospital's prescribed fasting times comply with the accreditation standards, this might be compromised if they started recording a skewed picture with very long fasting times, which nevertheless are 'real' from the point of view of the patient.

When elective-surgery patients fast longer than prescribed, it reflects a situation that the hospital can hardly control. However, the looming alternative of recording the actual start-time of fasting, provided by the patient, suggested such a big shift from the existing practice, that it led to discussion about the project's aim, questioning the purpose of recording fasting times, and the reliability of the measurements. *'Would we like to interpret [from the measurements] that the patients voluntarily begin to fast many hours too early? Would we like to work on reducing the fasting time? We have to ask ourselves what we want from this'* (Super User 3). The discussion about the aim of the project traced arguments from the initial effects-specification workshops: fasting for a long time causes emotional and physiological stress to the patient and is furthermore a known clinical risk factor for the elderly, the malnourished, diabetics, patients with ulcers, and others. Shorter fasting periods can be obtained only through better planning and coordination of surgeries; this might also lead to a better patient experience because, for example, if the operation is delayed, a fasting patient can get water or even food.

The discussion revolved around whether to use the prescribed fasting start-time in an attempt to comply with the national accreditation regime's aim of controlled processes rather than trying to improve the patients' treatment and experience through better coordination of the operations resulting in shorter fasting times. Gradually, the super users began to advocate for using the real fasting start-time. The meeting resulted in the decision to record the real fasting start-time for both elective and acute patients by asking the patient when he or she had last eaten.

The discussions above illustrate how the participants collaboratively defined the meaning of fasting time by bringing it into the foreground and discussing it in and through its multiple relations and multi-scoped connections. Infrastructural inversion, of the empirical-ethnographic kind, is manifest in the ways the super users followed relations within existing sociotechnical practices, organizations, and institutions as well as relations to envisioned future practices and conditions. In addition, they were motivated to pursue existing infrastructural issues, often found in and through mundane details they were already familiar with or willing to track down. Between meetings, the super users followed additional infrastructural relations to relevant scopes by tracing and inverting existing procedures, routines, and standards. During meetings, they shared their findings and views on relationships, associations, and interdependencies regarding fasting time as well as envisioned changes.

The discussions also illustrate how the generative strategy of infrastructural inversion was entwined in the infrastructuring process. The initial push towards a generative stance quite obviously came with the specified effect of 'shorter fasting time (in excess of the required 6 hours)' (see Figure 3) that repositioned fasting time from a minimal requirement that needs to be checked, to a visible tool for supporting tighter coordination in the scheduling of operations. This deliberate change agenda engendered generative inversions. The meetings instigated infrastructural inversion by starting to pursue the specified effect, and already early on future-oriented ideas were voiced, e.g. using the whiteboards to record fasting time and starting to calculate fasting

time (design-oriented relations shown in italics in Figure 4). However, the future-oriented ideas were challenged when it turned out that the taken-for-granted prescribed fasting start-time was not really a viable option, thus fasting start-time became the first major issue to be uncovered in detail, necessitating the inversion of relations to understand fasting as embedded in the mundane routines of how the hospital and the elective patients manage fasting. When real fasting start-time, provided by the patient, was considered, it introduced the uncomfortable situation that the medical staff was no longer in control of the fasting start time. The possible implications of changing to patient-defined fasting start-time were so drastic that the super users temporarily reverted to discussing the aim of the project. Then they revisited how fasting time connected with the arguments from the prior effects-specification workshops, with clinical quality assurance and with the Danish accreditation system. After all these multi-scope empirical-ethnographic inversions, they were ready to adopt a generative inversion for the fasting start-time, and the meeting concluded with the design decision to record the real fasting start-time on the whiteboards.

4.2 Defining the standard procedure for documenting fasting time

After having defined fasting time and when fasting begins the whiteboards were configured to include a new column (called 'Fasting from') to record patients' real fasting start-times and an additional time-counter column showing how long each patient had fasted. The meeting held in late March focused on defining the standard procedure of recording patients' real fasting start-times using the new columns.

The decision, from the previous meetings, to record the patients' real fasting start-time led to reflections on who should ask the patient when he or she actually started fasting (Figure 5). Many elective-surgery patients arrive at the hospital in the morning and, because they announce their arrival to the secretary, it was initially suggested that the secretary should record their fasting start-time. However, there are no secretaries during evenings, nights, and weekends. Thus, the focus was redirected toward the so-called patient-responsible nurse, who meets the elective patient upon arrival at the hospital. Reflecting on the current practice of the patient-responsible nurse the super users concluded that '*When the patient-responsible nurse meets the patient, they always ask if they are fasting. In this situation, you might be more specific and ask, "From what time have you been fasting?*"' (Super User 4).

The super users hesitated to have the patient-responsible nurse record fasting start-times for acute surgery patients because this would entail '*announcing it as a "must-do" task for the patient-responsible nurse*' (Super User 5). The patient was initially met by the patient-responsible nurse, but it is the surgical physician who decided when a patient needs acute surgery, and the recording of the fasting time should, thus, be the responsibility of the physicians. The super users knew, however, that it would be a challenge to make the physicians do this recording because they, in the super users' reading of the situation, were reluctant to adopt 'administrative' tasks. This opened the door to a sensitive area of hospital culture and hierarchy. In hospital culture, the nurses often were in the position of having to assist physicians in getting mundane, administrative things done. This was voiced in the following quote: '*I need motivation for doing this again: one more thing for the nurses to do for the physicians*' (Super User 4).

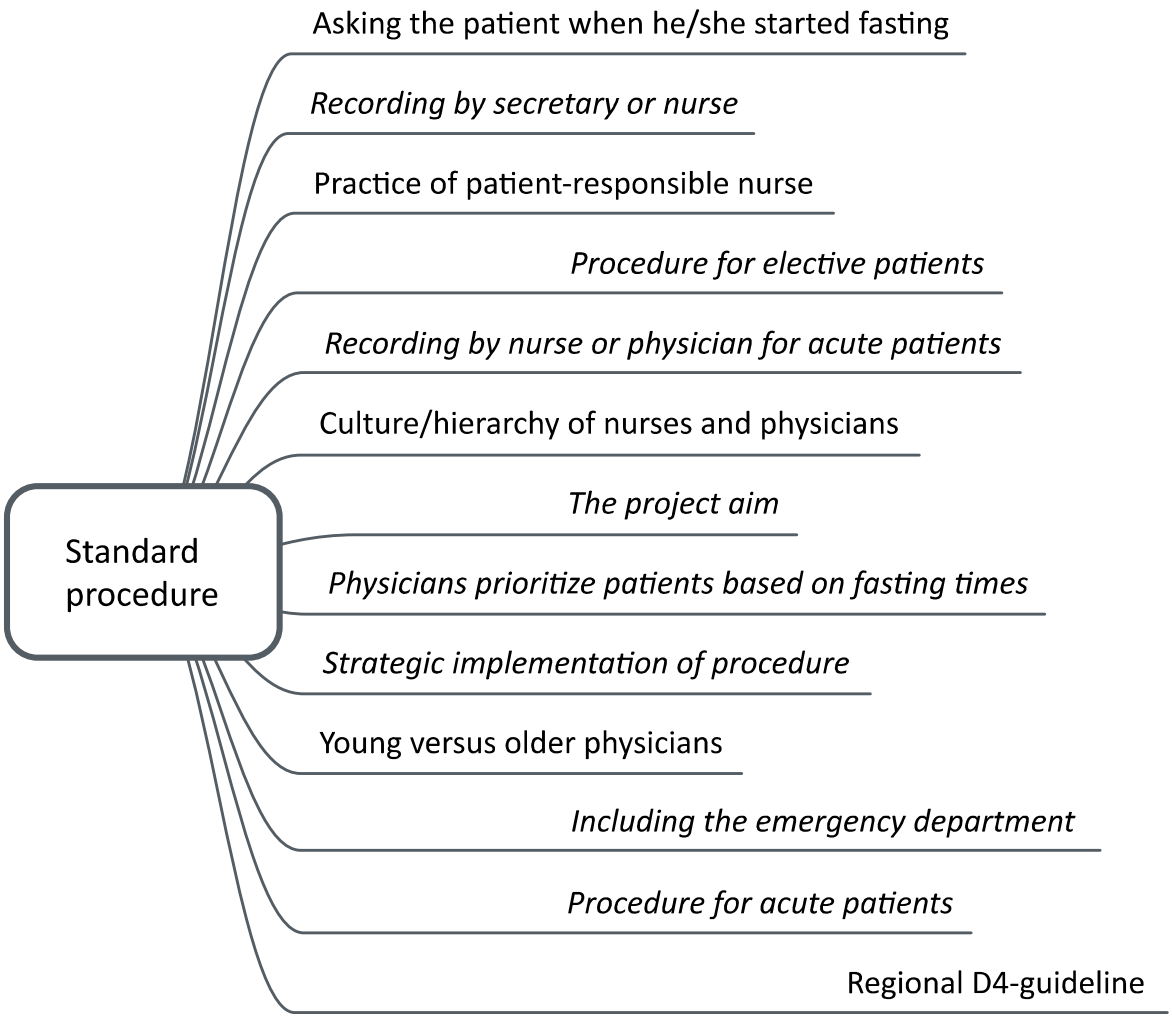

Figure 5. Relations traced, inverted and designed for in the process of defining the standard procedure for documenting fasting time during the meeting in late March, 2015.

The discussion led again to revisiting the aim of the fasting project:

> *'What we hope to achieve is that, if we start recording fasting start-time, the physicians will start to reflect on whether they should put patients in line as number 1, 2, 3, and 4. It will be visible to them that patient number 1 has 10 hours of fasting and patient number 3 has 2 hours. This is what we hope will happen, right?'* (Super User 3).

The visibility of fasting times was an important means to improve the physicians' planning and prioritizing of the operations: *'It is the physicians who are going to (re-)prioritize the order of the patients to be operated on the basis of their fasting times'* (Super User 4). This led to the conclusion that it had to be the physicians who record the fasting time for the acute patients, as summarized in the following quote:

> *'There are two aspects to this, and we have to—in one way or another—divide the recording of fasting start-time into who is doing it for the elective patients and who is doing it for the acute patients. For the acute patients, it's the surgeon who must record the patient on the whiteboard. He looks at the patient and observes that the patient has a broken arm and needs an operation. Then he records this*

on the whiteboard. And, in the same session, he asks 'When have you had your last meal?' They do that automatically. This is the point when he could record the fasting start-time' (Super User 3).

Considering the options of either the nurse or the physician recording fasting start-time for acute patients showed how the new idea was weighed by considering its embedding in established social arrangements, learned as part of – and shaped by conventions of – their community of practice including, for example, the super users' perception that nurses are expected to 'nurse' the physicians. It demonstrated the nurses' opposition to have to do 'one more thing for the physicians.' For the acute patients it made sense to have the physician (i.e. the surgeon) record the fasting start-time but it also opened the challenge of how to make them do it because they, according to the super users, were reluctant to undertake another administrative task.

After the super users made the decision to insist that the recording of fasting for acute patients should be the responsibility of the physicians, they considered how to implement the procedure strategically: Especially the older attending surgeons were known to respond to new procedures with a *'we don't have the time and we won't do the recording'* (Super User 3). A possible opening for making the physicians responsible for recording the fasting time was that, in practice, acute patients were identified by younger physicians in the emergency department: '*They are the ones who get the information about fasting start-times first – right?*' (Super User 4). These younger physicians were known by the super users to be more willing to adopt new work procedures and technologies, such as the electronic whiteboards: '*It should be this physician [in the emergency department where they have residents, i.e., younger physicians], they can enter the fasting start-time on the whiteboard for acute patients – they are really good at using computers*' (Super User 3). In addition, the procedure for booking an acute patient for surgery included a mandatory collaboration with, and authorization from, the attending surgeon (senior physician) from the surgical department, who was responsible for planning the operation: '*it is also the case that this young physician cannot book a patient for an operation until he has verified it with the attending surgeon*' (Super User 3). The strategy of using residents as proxies to involve the surgeon in recording the fasting start-time expanded the project's scope to include the emergency department – a department not originally involved in the project. Hereby, the procedure for acute patients reached closure, resulting in the complete procedure described in Figure 6.

1) Acute patients: The attending surgeon is responsible for the recording in the *'Fasting from'* column on the whiteboard at the time when the physician from the emergency department books the patient for operation.
2) Elective patients: The patient-responsible nurse records *'Fasting from.'*
3) Patients whose operation is delayed or cancelled: The patient-responsible nurse records a revised *'Fasting from.'*
4) *'Fasting from'* is defined as the time when the patient finished eating his or her last meal (not the time from when he/she ought to start fasting or when he/she was prescribed to abstain from food).
5) Using the *'Fasting from'* column is mandatory for the five departments [list of specific department names] comprising parenchymal and orthopedic operations. Other departments might be enlisted later if it becomes relevant.

Figure 6. The new local standard procedure for recording fasting start-time.

The draft of the local standard procedure for documenting fasting (Figure 6) was made during the meeting. The meeting ended with one of the super users agreeing to transform this draft into the standard template for the region's clinical guidelines, the so-called D4 guidelines. She would create a proposal for the new D4 guideline, and this proposal would be discussed at the next meeting. Then she would upload the proposal to the central database of D4 guidelines to make it accessible at all hospitals in the region. That is, by proposing the new procedure for recording fasting start-time as a D4 guideline it was communicated region-wide. Furthermore, proposals for new D4 guidelines entered into the regional quality-assurance system. This meant that the new standard would be forwarded to the regional quality-assurance committee as a proposal for a regional standard procedure for recording real fasting start-time.

The meeting demonstrates how empirical-ethnographic inversions are combined with inversing relations as a resource for change, including investigating how patients are approached to identify relevant situations for asking about the real fasting start-time. Making the fasting time visible through two new columns on the whiteboard (displaying the 'real fasting start-time' and the corresponding 'accumulated fasting-time') opened for the possibility to draw the physicians' attention to patients with long fasting times. The generative-designerly infrastructural inversion resulted in crafting a standard procedure for documenting fasting start time for acute patients based on the knowledge and experiences of young versus senior physicians. The strategy for implementing the procedure demonstrates how the infrastructural changes shape and are shaped by the conventions of the community of practice: the super users are confident that they can introduce a new administrative task to the young residents and that this can trigger the involvement of the senior surgeons. Consequently, the project's scope is extended to include the emergency department. By expanding the scope this procedure instructed the young physicians to record the fasting start-time. And since this entailed a mandatory authorization from the more senior attending surgeon, it potentially motivates the attending surgeon to inspect and reconsider the schedule of operations.

In addition, the new local standard procedure was extended to regional scope by transforming it into the form of a standard D4 guideline. Clinical standard guidelines are well-known to the healthcare sector in general and to hospitals in particular. Drawing on their analysis of current practices and infrastructural relations, the super users defined a new local cooperative standard procedure, devised a way of implementing it for their hospital, and were confident to explore outwards the connective capacities of their generative thinking. As no prior regional standard existed for documenting real fasting time, the new procedure was crafted and submitted to the region as a proposal for a new D4 guideline. Thus, the designerly-generative scope was extended from the local to the regional level.

5 Discussion

The PD project analyzed in this article aimed at integrating the electronic whiteboards in the local healthcare information infrastructure to strengthen the interdepartmental coordination of operations, by focusing on fasting times. The project started from the assumption that preoperative fasting was a rather unambiguous concept but, gradually, the complex relations and issues concerning fasting time and surgical coordination were unveiled. This unveiling happened through infrastructural inversion carried out for the most part by hospital personnel engaging in the infrastructuring process. The analysis documents this evolving process paying specific attention to how the participants traced, inverted and designed for relations and their connectedness over various scopes comprising the hospital setting, patients' lifeworld, as well as larger regional and national spheres. Our study reveals a highly sociotechnical process that presupposes local knowledge and foregrounds that the 'local' issues are also part of multiple webs of relations that connect to different extents beyond the wards and the hospital. The account tracing these relations uncovers their connectedness and documents how they are inverting embedded and inherent practices (current 'as-is') as well as generating changes to fasting-time management in designerly ways (*future 'to-be'*).

5.1 Tracing, inverting, and designing for infrastructural relations

In the meeting discussions, the super users related the notion of fasting time in various ways with diverse considerations, such as the installed base of existing tools, work practices and procedures, as well as different types of patients, professional roles and responsibilities. Moreover, it was not enough to focus on local existing practices, instead relations were traced beyond the boundaries of the participating wards to the entire hospital, regional standards for clinical processes and the Danish accreditation system. Thus, relations were pursued over multiple relevant reaches and scopes (Star, 1999; Star and Ruhleder, 1994; 1996; Karasti and Blomberg, 2018). The work of following, mapping, analyzing and making sense of relations unfolded and extended until the super users established a sufficient and satisfactory understanding from their positions and points of view, which included understandings of current practices, awareness of the multiplicity of

related issues and concerns, and the various infrastructural scopes involved. These understandings gave rise to the inductively created characterizations, categorizations and considerations of infrastructural relevance and consequence, such as distinctions between elective and acute patients, deliberations on fasting start-time, extensive reflections on local standard procedures for recording and enacting fasting time, and its crystallization into a proposal for a regional guideline.

The super users foregrounded, analyzed and partly critiqued existing practices and procedures while continuing to envision alternatives for how to handle that work and how to coordinate fasting time with whiteboard infrastructure support. Thus, the super users made both 'analytic moves' and 'design moves' by shifting from identifying and scrutinizing existing relations to articulating new, anticipated relations and connecting them over various scopes. These shifts illustrate the generative potential of infrastructural inversion (e.g., Kaltenbrunner, 2015) and how this generative potential may coincide with a design agenda. What the project participants ultimately ended up with, however, was not the initial objective of improved coordination within the hospital – a goal too distal from the limited time frame of the PD project – but rather a series of smaller but essential changes towards this aim: the networked whiteboards would allow a new way of recording, calculating and presenting fasting time at the local level, which previously did not exist as numerical indicators but rather as a simple checkmark indicating a patient being on the safe side of the fasting criterion. This new local standard procedure was then translated into a submission for a new D4 guideline standard at the regional level, including a new delegation of how actors would record and act on fasting start-time, affecting how fasting time is both defined and also practiced at other locations beyond the hospital in question. These changes not only illustrate the tracing, inverting and articulating of old and new relations (epitomizing empirical-ethnographic and analytic-conceptual infrastructural inversions), but also highlight the concrete outcomes of the project manifested in actual changes in practice across multiple scopes, and whose effects are likely to reverberate well beyond the local setting under investigation (exemplifying generative-designerly infrastructural inversion). Kaltenbrunner (2015) argues that defamiliarization and critique of existing practices are integral to generative infrastructural inversion. We maintain, however, that it was the super users' familiarity with, appreciative knowledge of, and critical analyses of the clinical work in all of its relevant relations and connections that were essential for the design outcomes in our case.

5.2 Lessons for participatory design

During the project, the PD researchers often felt frustrated because project progress seemed slow. We experienced several situations that might be characterized by us thinking, for example: '*Now again we are side-tracked into other discussions, we should get back on track and move on designing the planned solution. How come we constantly are "interrupted" by all these side-tracking issues and discussions?*' What was at stake in those situations has to do with infrastructural inversion, uncovering mundane infrastructural issues embedded in their multiple relations, which affect many other more or less stable practices, procedures, constellations, norms, cultures, technologies, terminologies, etc.

We propose that to integrate infrastructural inversion into PD, it is important to make room for both the empirical-ethnographic, analytic-conceptual and generative-designerly infrastructural inversions by leaving the process and means of achieving the inversions open. We experienced that the effects-driven participatory approach (Hertzum and Simonsen, 2011) facilitated the needed openness. The approach focuses on the desired effects and *leaves the process open* for the user-participants to learn, understand, and experiment in various ways to realize these effects without insisting on any specific methodological techniques or guidelines for how to do this (Simonsen, et al., 2018). At the meetings, tracing, inverting and designing for infrastructural relations followed by reaching closure were enabled by the open agenda of the meetings that provided ample space for discussion and did not stipulate rules for how or what to discuss, apart from an overall focus on the project aim. In our experience, this required that we assumed an engaged and enabling, but also patient role. To facilitate the exploration of relations the PD researchers' (or more generally, the designers') role is to encourage an exploratory attitude but otherwise largely just *actively*

listen, and adopt a wait-and-see attitude. The designers will likely be more actively involved in reaching closure by summing up and by verifying whether agreement has been reached. This aspect of PD facilitation contrasts with a traditional PD designer role of actively staging workshops and facilitating or managing ways to engage users in activities of telling, making and enacting (e.g. Brandt et al., 2013). The need for the designer to 'slow down' to attune to the ongoing dynamics, in our case the participants' unearthing of relations and connections relevant to their worlds, has been put forward by Michael (2012), Yndigegn (2016), and Pihkala (2018); all drawing on work by Stengers (which are collected into a recent book, Stengers 2018).

Our empirical analysis documents a role for the user-participants investigating the complex webs of relations that influence their work. By engaging in infrastructural inversion, the participants unravel a rich set of relations. This ability is based on *local knowledge* and competence in using it to link everyday activities to an expanding web of issues, relations, and connections. This is indeed an arena where the user-participants excel: they know the domain, are deeply involved and acquainted with the work practices and particulars of the local setting and therefore well-positioned to uncover its 'hidden' issues of relevance. In our case a small project group of dedicated local user-participants (the super users) was established to carry out the demanding task of unraveling the relations, which involved domain-specific operational coordination and category/standards work. Some of this was known to them (maybe partially unarticulated in the beginning), and some they were somewhat aware of and needed to find out in more detail by following the leads they knew of or learned about during the project. The user representatives cannot have concrete, practice-based knowledge about all the relations; for some relations, they will only have abstract knowledge (Kensing and Munk-Madsen, 1993; Bødker et al., 2004). For instance, the physicians were notably absent from the project group, and it was therefore a recurrent problem to trace relations regarding their activities and perceptions with sufficient accuracy. When infrastructural work is conducted by a small group, the connectedness of the relations creates a recurrent need for the participation of other knowledge representatives outside the group.

The inherent need for local knowledge brings an obvious relevance to combine infrastructuring with PD. But it also introduces challenges which in many ways are unfamiliar to PD. PD perspectives might need to 'slow down' and/or engage with approaches that impinge few process prescriptions, such as the effects-driven PD approach (Hertzum and Simonsen, 2011), thereby entrusting the users the necessary space and time to pursue and work with infrastructural relations through multiple scopes.

5.3 Infrastructuring and participatory design

In relation to infrastructuring PD might not involve the design of new IT, rather at issue may often be to 'build on technologies, competencies and practices that already exist' (Bødker et al., 2017, p. 245). In our PD project infrastructuring concerned reconfiguring existing, but not yet fully integrated technologies (the networked electronic whiteboards) to support the aim of improving existing competencies and practices regarding the coordination of operations and the management of fasting times. A PD approach to infrastructuring may involve sociotechnical change connected to a large installed base of different interrelated sociotechnical systems, as an ongoing effort (Aanestad et al., 2017). This involves multiple and different actors and comprises engagement in changing established organizational settings, procedures, and practices. And it comprises reconfiguring both the available technical systems and their associated and socially embedded use practices. It is evident from our case, that the seemingly mundane detail of introducing two new columns on the whiteboards, which in technical terms is a small reconfiguration, opened to a wealth of sociotechnical, multi-scope infrastructural issues to be inverted, discussed and decided.

Design-oriented approaches are 'aimed at changing existing situations into preferred ones' (Simon, 1981, p. 111) and they are characterized by their intentionality towards a specific outcome through an exploratory, experimental, and highly emergent process (Simonsen et al., 2010). Karasti and Blomberg (2018) point to the multiple forms of intentionality subjected to information infrastructures and infrastructuring through a family of 'ing' terms such as growing, fostering, cultivating, making, fixing, adapting, maintaining and

repairing. The overall, formally stated and often returned to intentionality inherent in the design-oriented approach in the effects-driven PD project was rooted in the project aim of improving the interdepartmental coordination of surgical operations at the hospital and, more specifically, shortening the patients' preoperative fasting times. This intention is interlaced in the *rhythms* or temporal patterns (Zerubavel, 1979) of participants' activities: the infrastructural inversion uncovering and making sense of relations and connections – referred to above as the empirical-ethnographic and analytic-conceptual form of infrastructural inversion – *and* laying the ground for making design moves – referred to above as the generative-designerly form of infrastructural inversion. In the fasting-time project we observe an alternation between those two forms of inversion, on the one hand, exploring and tracing relations to existing practices and, on the other hand, condensing and reaching closure through design-oriented relations pointing to future practices.

The rhythmic alternation manifested *during the individual meetings* which introduced, traced, inverted, analyzed, and resolved multiple issues through their short temporal lifespan. During each meeting, the discussions traced multiple relations in parallel with only a rough agenda guiding the discussion and helping determine which relations to trace. The inversions started in the 'here and now' of the 'local' by analyzing existing practices and identifying relations for infrastructural tracing: the empirical-ethnographic form of infrastructural inversion. The tracing of relations proceeded from within the local 'here and now' to map relations over different scopes. It also proceeded by tracing historically accumulated relations inscribed in materialized forms, such as clinical procedures, classifications, standards and technologies. In addition, on occasion, the inversions worked as 'generative resources' that participants could draw on in infrastructuring. In these cases, the infrastructural inversion 'leaned forward' in that participants engaged in envisioning and projecting future relations of relevance. The relations to envisioned future practices most often brought at least temporary closure to the investigated issues, as documented in Section 4.

A rhythmic alternation was also visible on the *PD project level*. This rhythmic alternation corresponded to the three overall activities of the effects-driven approach (Figure 2): identifying which effect to pursue, realizing the fasting-time effect, and responding to the fasting-time measurements. These project activities are reflected in the meetings, where fasting-time explorations were guided by themes (topic areas) set by the design agenda. These themes included how to define fasting time; how to represent the fasting time on the whiteboard through new columns; how to standardize the work procedure for recording the fasting time (there were naturally more themes addressed in the entire project but here were have focused on meetings dealing with these themes). While infrastructural inversion was key to the exploratory activities of following relations, it did not by itself resolve the explored issues. Rather, the infrastructural inversion led to an exploration, which could trace and invert, in principle, an unlimited number of relations. The need for closure came from the project's overall rationale to improve operational coordination, i.e. from the project aim and design agenda. The activities of exploring and making sense of relations converged to produce closure in the form of outcomes expected in the design agenda – namely, the redefinition of fasting time as a category, the representation of fasting as two new whiteboard columns, the standard procedure for the hospital-wide use of the new whiteboard columns, and the formulation of this standard procedure for a regional standards body. Closure was reached for each topic, even if only temporarily and limited to the participants present at the meeting. Most often the PD researchers facilitated closure and reaching conclusions by referring to the aim of the project and overall project activities (Hertzum and Simonsen, 2019). In other words, the PD researchers undertook the role of bringing the inversions back to the formally stated intentionality of the PD project (reaching closure) rather than letting the hospital actors' and super users' inversions unfold ad nauseam (exploration).

The open-ended explorations of tracing and inverting became a way to provide the basis needed for analysis and decisions about how to move forward. This way, alternations between exploration and closure made the project activities both relationally and processually oriented. In light of the recent theoretical problematization of assuming straightforward and easy moves from the relational to the processual notion

of infrastructuring (Karasti, 2014), our analysis illustrates how in practice both the relational quality of infrastructures and the processual nature of design can be carefully heeded through the rhythmic alternations between exploration and closure. Thus, they can co-exist and thrive in infrastructuring. This aspect of infrastructural inversion is less explored and not yet theorized (Kaltenbrunner, 2015) but seems to offer a promising opening for infrastructuring and other design-oriented approaches. Hence, *we propose that a defining quality of infrastructuring is that it makes room for and balances relationally-oriented infrastructural inversion and processual, forward-leaning design: This positions infrastructural inversion as an analytic, empirical and generative notion.*

6 Conclusion

In this article, we have analyzed the issues, relations and connections that were traced and inverted during the infrastructuring process of a PD project that aimed to improve the coordination of surgical operations by focusing on reducing patients' preoperative fasting. Our empirical results document specific mundane infrastructural relations on a concrete and detailed level. We have shown how the analytic-conceptual and empirical-ethnographic infrastructural inversion and the generative and design-oriented infrastructural inversion are, in important ways, interleaved in the process of infrastructuring. Our contributions include: *First*, we have identified and presented the concrete relations that were traced and inverted during a local infrastructuring process. These relations were followed through multiple reaches and scopes, so that relevant issues were considered, and actions taken. We find that tracing and inverting infrastructural relations enriched the PD process by revealing the webs of relations in which fasting time was inscribed and by showing their connectedness. *Second*, inverting infrastructural relations required local knowledge about practices and constraints and it required competence in using this knowledge to link day-to-day work conditions to the expanding web of relations relevant to the design process. This points to the need for approaches that make room for infrastructural inversion and for PD designers who are willing to listen and slow down in their facilitation. *Third*, our analysis shows how infrastructural inversion and design intertwined into an infrastructuring process that alternated between exploring relations and reaching closure. This rhythmic alternation was present at the individual project meetings and can also be observed at an overall project level reflected by the effects-driven PD approach. Infrastructural inversion can, in principle, trace unending webs of relations. It is imperative that the infrastructuring process reflexively maintains a balance between, on the one hand, making room for pursuing a rich variety of relations and, on the other hand, reaching closure to move forward. This seems possible by balancing relationally-oriented infrastructural inversion against processual, forward-leaning design. *Fourth*, infrastructural inversion is not merely a means of making visible that which otherwise remains invisible, it also encompasses transcending the 'here and now' – materially, spatially, temporally as well as organizationally. By seeking to uncover the multi-faceted, relationally embedded, and connected conditions of work practices, the gestalt switch of infrastructural inversion goes beyond articulation work, which is conducted to get things back on track – locally and temporarily. It is the extended reach and scope of infrastructural inversion that makes it particularly relevant for infrastructuring.

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