

An Afterword to ‘Infrastructuring and Collaborative Design’

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1. Introduction

This issue of *Computer Supported Cooperative Work* (vol. 27, no. 2) is the second and final part of the three issues focusing on the topic of ‘Infrastructuring and Collaborative Design’. The first part of the special issue was published as a double issue (vol. 26, nos. 1-2) in 2017. Eight articles were published in the first part, and this second part includes four articles, making a total of twelve articles.

Amidst the wealth of journal special issues and edited books on (information) infrastructures (Edwards et al. 2009; Lee et al. 2010; Graham and McFarlane 2014; Monteiro et al. 2014; Appel et al. 2015; Karasti et al 2016; Harvey et al 2017; Jensen and Morita 2017), these special issues in *Computer Supported Cooperative Work* are the first to focus particularly on research that engages with a processual (in-the-making) perspective and/or design-oriented engagement with information infrastructures. We have developed this under the rubric of ‘infrastructuring’.

In this afterword to the special issues, we first introduce the remaining four articles, and then review the collection as a whole. Drawing on the special issue articles and existing literature, we discuss dimensions of infrastructuring relating to analytic, methodological and design issues. Further, we consider what this collection of articles tells us about the state of the art in CSCW’s understanding of Infrastructuring and Collaborative Design. We conclude by looking forward to the challenges and opportunities still on the horizon.

2. Articles in this third and final issue

Crabu and Magaudda’s (2018) article ‘Bottom-Up Infrastructures: Aligning Politics and Technology in Building a Wireless Community Network’ is based on an investigation of grassroots information infrastructure building and maintenance in Italy. This year-long multi-sited empirical case study encompasses qualitative interviews with participants of four local networks and ethnographic observations of three major meetings, and analysis of the existing documentation of Ninux.org and participants’ collaborative forms of communication on local and national levels. Drawing on recent STS concepts of ‘inverse infrastructure’ and ‘research in the wild’, the authors unfold the mutual shaping of technical activities and participants’ political views and motivations in infrastructure building localized outside the more conventional spaces of research and development. Crabu and Magaudda draw particular attention to the mutual reconfiguration between the technical, the political, and the social involved in ‘infrastructuring in the wild’: the

alignment and ‘generative contamination’ of the complex terrain where participants’ motivations, meanings, and identities are shaped, transformed and reinforced together with technical aspects of the processual and in-the-making creation and maintenance of a grassroots infrastructure.

‘Infrastructuring as Ambiguous Repair: A case Study of a Surveillance Infrastructure Project’ by Mikaelson et al. (2018) reports on an investigation of a health care and welfare surveillance infrastructure in a Norwegian municipality setting. Based on a longitudinal, multi-site and multi-method empirical study and an understanding of infrastructuring as involving a variety of intertwined change processes of different scope, the authors investigate how the people involved in the project deal with the convoluted ambiguities. With a focus on how the project moves through iterations of breakdown and repair in order to implement a working system, the authors identify three interconnected collaborative repair mechanisms along three dimensions: value-network, process and participation repair. Drawing attention to ambiguities and tensions as an inherent and always present part of infrastructuring, the authors suggest considering ‘ambiguous repair’ as an ongoing and necessary part of infrastructuring that also encompasses generative and innovative potential.

Many infrastructuring processes and phenomena emerge from the “installed base” (from what is already there) and are strongly influenced by the network of existing dependencies. With some very innovative or radically new technological concepts, the infrastructures that emerge are not only influenced by existing relations and dependencies, but also by imagined or envisaged relations. Kow and Lustig (2018) look in their paper entitled ‘Imaginations and Crystallization Processes in Bitcoin Infrastructuring’ at infrastructuring activities around the probably best-known example of using blockchain technology. They make use of the Neumann and Star’s (1996) use of the concept of ‘imaginaries’ to document how the actors involved in infrastructuring bitcoin platforms and protocols use narratives to illustrate and negotiate their ideas and concerns to allow a crystallization process to emerge that guides the activities of participants, be it along a shared narrative, be it ‘imaginaries branching’.

‘Studying infrastructuring ethnographically’ from Karasti and Blomberg (2018) is the most methodologically oriented paper in this special issue. While empirical work has been part of each and every study published in the special issue, this paper turns to issues and concerns accompanying an infrastructuring effort as a methodological challenge. The approach of perceiving an ethnographic field not as a given, but as something being constructed while exploring the field is core to the way ethnographers need to deal with the relational and emergent phenomena around infrastructuring efforts. Karasti and Blomberg suggest five dimensions of information infrastructure which constitute a major development of Star and Ruhleder’s classic definitional work (Star and Ruhleder 1994; 1996). These dimensions are used to carefully describe how inverting infrastructural relations, following connections, discovering discontinuities, and extending and reflexively bounding the field can provide guidance in continuously ‘constructing the field’ when accompanying infrastructuring efforts ethnographically.

3. An overview: Reading across the collection

In putting together this special issue we aimed to assess the current state of CSCW’s contribution to the understanding of infrastructuring and collaborative design (Pipek et al. 2017). In the call for papers we highlighted new, original challenges to contemporary CSCW and design in general, that infrastructuring proposes, such as: “extending the temporal, organizational, societal scopes and

diversifying collaboration arenas from the common use, design and development to tailoring, appropriation, repair, maintenance and standardization, to including professionals from industry, formal organizational structures like standardization bodies and authorities as well as community members and citizens in informal, community-based initiatives” (ibid., p. 1-2). The authors of the articles in these special issues have responded by addressing the challenges of complexity, extended scopes, and diversity in a rich and constructive way.

They all, except for the two specifically methodologically oriented ones, provide detailed studies of infrastructuring in a given empirical setting, by investigating what is actually being implemented and taking place in infrastructuring as collaborative design. They do not shy away from the complex socio-technical relations and arrangements extending over multiple scopes, but pay attention to the ambiguities, tensions, power issues and politics encountered in these settings. As such, articles in this collection contribute to the growing body of studies of infrastructuring in varied socio-politico-technical settings, which lay the framework for future comparative work.

The twelve articles published in this special issue, while all viewing their material through the lens of infrastructuring and collaborative design, have covered a range of substantive fields/domains, including information infrastructure development for healthcare and welfare (Grisot and Vassilakopoulou 2017; Ulriksen et al. 2017; Mikaelson et al. 2018), infrastructuring for cultural commons in digital cultural heritage (Marttila and Botero 2017), formation of ‘publics’ around the theme of dyslexia (Menéndez-Blanco et al. 2017), voting technology deployment in digital civics (Lindley et al. 2017), infrastructure development for a new cross-disciplinary synthetic science field of Land System Science (Young and Lutters 2017), infrastructuring in an oil company (Parmiggiani 2017); infrastructuring in education (Bødker et al. 2017), grassroots infrastructure development for wireless community network (Crabu and Magaudda 2018), and infrastructuring an open source digital currency and payment platform, Bitcoin (Kow and Lustig 2018), and last, in a somewhat different vein, discussing how to study information infrastructure as an empirical real-world phenomenon of infrastructuring (Karasti and Blomberg 2018).

These articles demonstrate the interdisciplinary tradition core to Computer Supported Cooperative Work (CSCW). We have not carried out a methodical survey of the disciplinary origins of the authors, however it is clear from their institutional locations as well as their substantive foci that the authors come from an array of backgrounds including information systems/informatics; telemedicine and e-health; interaction and interactive technologies; arts, design and architecture; research units in IT industry; human-centered computing; computer science; participatory design; science and technology studies. The geographical spread is also broad, including authors from Denmark, Finland, Hong-Kong, Italy, Norway, Portugal, the United States of America, and the United Kingdom.

Taken together, the papers suggest that the study of infrastructuring is on increasingly solid theoretical ground. Across them, we see a confidence in identifying related sets of socio-technical developments as infrastructuring and applying to them a relatively stable set of theoretical resources. All articles make reference to the initial work by Star and colleagues on information infrastructures characterizing infrastructures as relational and situated (including Star and Ruhdeler 1996; Newman and Star 1996; Bowker and Star 1999) and most also to its ‘how to infrastructure’ variant that emphasizes the processual, in-the-making quality and perspective of ‘infrastructuring’ (Star and Bowker 2002; Karasti and Baker 2004; Karasti and Syrjänen 2004; Pipek

and Wulf 2009; Karasti 2014). In addition, many articles in the collection integrate further theoretical notions and conceptual tools mainly from the fields of Science and Technology Studies (STS) and Information Systems (IS) into their analyses, including the ‘biography of artifacts’ (Menéndez-Blanco et al. 2017), ‘commons’ (Marttila and Botero 2017), ‘inverse infrastructures’ and ‘research in the wild’ (Crabu and Magaudda 2018), ‘repair’ (Mikaelsen et al. 2018), ‘publics’ (Menéndez-Blanco 2017; Lindley et al. 2017), and ‘tensions’ and ‘imaginaries’ (Kow and Lustig 2018), ‘knotworks’ (Bødker et al. 2017) in particular comes from activity theory in the work of Yrjö Engeström.

4. Analytic Issues Across the Collection

When we talk about ‘infrastructuring’, the gerund is central. What’s in a verb? As David Bohm (2013) or Alfred North Whitehead (Stengers 2011; cf. Latour 1993) argue, it is about moving from a fixed to a process ontology. And this is the central fact about ‘infrastructuring’ – it is not that the act of building an infrastructure ever simply ratifies pre-existing relationships: the act of infrastructuring changes what it is to be a road, a unit of currency or an ecology. Infrastructures are engines of ontological change. They stand between people and technology and nature and in so doing reconfigure each simultaneously. Core to our vision for these special issues has been an understanding of the perpetual refiguring which is at the heart of infrastructuring. Crabu and Magaudda (2018) bring this out in their study of bottom-up infrastructures, where the distinction between ‘expert’ and ‘lay user’ is on the table from the start. They argue that infrastructuring is partly *about* identity construction. It is not that we have the fixed category ‘people’ adapting to a predetermined technical infrastructure: rather people and infrastructure become different kinds of things through the process of infrastructuring.

Developing this point further, Mikalsen et al. (2018) look at health and welfare surveillance procedures in residential homes. They identify the lovely problem of ‘pilotism’: at the heart of infrastructuring was the issue that procedures and outcomes were not fixed from the start, but changed along the way. They bring out a core aspect of recent studies of infrastructure, highlighted first in Steve Jackson’s work: repair is a constant part of the process (Jackson 2014). What is being ‘repaired’ in an infrastructure can be just as much a process or a model or participation as a technical feature. These two works speak to the issue of temporality, which is a recurrent one throughout these special issues. In moving beyond the traditional engineering vision of an engineer ‘in here’ creating an application or a piece of technology and throwing it ‘out there’ or ‘over the wall’, we need to begin to analyze the complex sets of feedback between technology and technique, process and identity. The very concept of infrastructuring asks us to move beyond a linear temporality (if this, then that) to a more modulated one, in which ‘design’ acts as the verb which modulates subject and object simultaneously. And, crucially, ‘design’ is not the prerogative of the designated designer: designing emerges from the sets of interactions among engineers, users and technology. It is decentered.

Lindley et al. explore issues of the constitution of multiple publics, in a Deweyan sense, by discussing two experiments in mundane voting technologies (2017). Moving beyond the dichotomy between user and designer, they emphasize: “the idea of infrastructuring as a means of supporting the formation and recognition of multiple publics”. We often think of infrastructures as monolithic achievements – literally in the case of the Hoover Dam or figuratively when we think naively about airline transport, container ships or the Internet. This kind of vision of ‘us’ being affected by ‘technology’ and yet fundamentally unchanged by it goes back to Landes (2008 [1969]) and before. It is precisely what Veyne (1978) is talking about when he seemingly paradoxically

praises Foucault for being a true historian (Foucault's *discourse* had until then been seen as timeless; only affected by the irruption of unexplained epistemic breaks). Veyne shows how under Foucault concepts such as 'democracy' or the 'liberal subject' cannot be the same under new technological infrastructures: we are different publics as well as different people as we inhabit new infrastructures.

The concept of 're-infrastructuring', introduced by Grisot and Vassilakopoulou in the context of eHealth services is very useful here. We should not think that once an infrastructure has been built, its qualities (social and technical) remain true forever. This was a common error of early science and technology studies, typified by Latour's otherwise wonderful paper on technology as society made durable (Latour 1990). The great contribution of the studies in these issues, is to say that because designing is a continuous process so is infrastructuring – and that therefore everything that was up for grabs in an original infrastructure (categories of use, designer, user, public and so forth) always remain changeable – albeit at differing rates of temporal flow/viscosity. Ulriksen et al. develop this theme of temporal viscosity by looking at two separate but interrelated temporal scales of infrastructuring (2017). The concept of re-infrastructuring sensitizes us to this interplay. Just as the 'liberal subject' is not what she was in a new sociotechnological infrastructure; so is the 'radio' a different kind of thing as new acts of (re)infrastructuring take place. Parmiggiani's paper is highly resonant here, when she talks about different scales of infrastructuring; and in her rich assertion that: 'infrastructuring highlights the unbounded nature of collaborative design' (2017).

Ulriksen et al. also speak (2017), as do Young and Lutters (2017) to the issue of breakdown – be it in an infrastructure to locate 'relevant global datasets' or one to address electronic health records. The issue of breakdown was core to Star and Ruhleder's (1994, 1996) definition of infrastructures (they become visible on breakdown). In a process of infrastructuring, the 'breakdown' is never as simple as a light not turning on as you flip a switch because the circuit breaker has been triggered. To the contrary, the design space – as all of these papers have demonstrated – is much wider in 'infrastructuring' – you may need to 'fix' the public, individual identities, social groups as much as technical artifacts. Menéndez-Blanco et al. specifically call out this wider design space: "Such results go beyond the enactment of a specific digital platform, and call for stronger interdisciplinary connections with, for example, sociology and anthropology to understanding the potential public and their forms of involvement – and commitment – or with public communication" when looking at the infrastructuring of dyslexia in Italy (2017).

Finally, Kow and Lustig (2018) bring us back to the central aporia of infrastructuring: it is simultaneously about relatively unbounded imaginaries ('collective visions, motivations, and common ground') and about the need to crystallization (something needs to work at the end of the day). For the latter, their act of crystallizing onto a boundary object keeps open the design space which is central to infrastructuring.

5. Methodological issues in studying infrastructuring

Infrastructuring as a relational and emerging phenomenon poses methodological challenges. Researchers basing their investigation on empirical approaches are required to adapt their methods, empirical fields of investigation, and objects of analysis to grapple with such phenomena. Initial methodological developments have provided tools and orientations for studying the mundane and the invisible (Star 1999), such as the 'infrastructural inversion' suggested by Bowker (1994) to focus on the activities that warrant the functioning of

infrastructure rather than those that it invisibly supports. In this section, we will take a look into the variety of methods and study designs employed in the articles in these special issues and offer some thoughts for future research.

The articles in this special issue are either by authors who reflect back on an empirically grounded design project in which they have engaged or by authors who report from their empirical investigation of an infrastructuring undertaking. Thus, methodologically speaking, all articles are grounded in empirical studies, with the exception of one that nevertheless also speaks to empirical studies of infrastructuring but does so with a broader interest in onto-methodological concerns associated with studying infrastructuring ethnographically (Karasti and Blomberg 2018).

5.1. Empirical methods applied

The articles that build on empirical work, employ a variety of research methodological approaches, ranging from no research method described but a case study used to illustrate the chosen conceptual framing and argument (Bødker et al. 2017) to detailing multi-method approaches (Mikaelsen et al. 2018; Menéndez-Blanco et al. 2017; Crabu and Magaudda 2018; Ulriksen et al. 2017; Grisot and Vassilakopoulou 2017; Young and Lutters 2017; Lindley et al. 2017). In addition to ethnographic (Ulriksen et al. 2017; Parmiggiani 2017; Kow and Lustig 2018), qualitative multi-method (Crabu and Magaudda 2018), and qualitative interpretive approaches (Grisot and Vassilakopoulou 2017; Mikaelsen et al. 2018), the assortment includes approaches with different degrees of researcher engagement with the design projects studied (Bødker et al. 2017; Lindley et al. 2017; Young and Lutters 2017; Marttila and Botero 2017). Furthermore, one study reports of integrating an ethnographic approach with involvement in design during the project (Young and Lutters 2017). This is indeed a wide-ranging methodological spectrum for the study of infrastructuring, in comparison, for instance, to the collection of articles in a recent 'sister' special issue on 'Knowledge Infrastructures' in *Science & Technology Studies* journal (Karasti et al. 2016) where twelve papers out of the total of fourteen were ethnographic studies.

5.2. Study designs

Several of the articles based on ethnographic and qualitative approaches rely on a widely-trusted set of empirical methods, typically consisting of participant observation, interviewing and document analysis (Crabu and Magaudda 2018; Grisot and Vassilakopoulou 2017), with some study specific added extras, such as Young and Lutters conducting a community survey (2017), Ulriksen et al. collecting system logs (2017), and Mikaelsen et al. making field trips to health and welfare centers where the same system they studied had been implemented and visiting residential homes (2018). These additions suggest some adaptation to the empirical setting of investigation in negotiation with the authors' research interests.

An interesting contrast to the above-mentioned multimethod approaches are three articles that report on an analysis of only a certain limited set of data collected with one method (Kow and Lustig 2018; Lindley et al. 2017; Menéndez-Blanco et al. 2017). Typical of these articles, however, is that the authors also describe the more extensive empirical investigations within which the article is based. The article by Lindley et al. (2017) reports on what the researchers learned of the experience of household members participating in the study by interviewing them, but the authors rather extensively also describe the deployment of voting technologies in neighborhoods, and other connected ideas of the study. Kow and Lustig (2018) report on participant observation

of two Bitcoin conferences, however, extensively also describing the larger project and citing their earlier publications that report on other collected sets of data. Furthermore, Menéndez-Blanco et al. (2017) provide quite extensive information about the case study of spazioD and the design context of dyslexia, and how the researchers participated in several public events, for example seminars at schools, meetings organized by associations, and groups of parents, how they analyzed a large set of data collected through websites and social networks, and performed semi-structured interviews involving government officers, educators and parents. However, what is actually said to be reported in the article is how the Facebook page, created as 'community page', contributed to infrastructuring, based on the findings of Facebook log analytics, embellished by participating people's comments on them, as well as designers' and researchers' reflections. We could, of course, read these examples as abiding to the tradition of having to publish some new data in each article, enforced, for instance, for doctoral studies publications, or as skillfully reporting different aspects and different data of the same, larger investigation to different outlets and audiences. Another interpretation, based on the observation of the rich detail provided of the study context that the authors, understanding the relational quality and complexity of the larger settings of infrastructuring, feel responsible to communicate to their readers, so that the new findings can be understood more fully in relation to their more extended contexts.

The article by Kow and Lustig (2018) is of interest also in how it can be read as an example of incrementally constructing the field (Amit 2000). In this article Kow and Lustig nicely continue to report on their sustained research interest in the Bitcoin phenomenon, by both building on their previous experience and fieldwork, and here adding a new instance of fieldwork, i.e. participant observation of two Bitcoin conferences, as an extension to the multi-sited ethnography they are gradually constructing. As the authors say: "This article extends our previous studies by examining development constraints faced by these stakeholders, and their strategies to overcome them" (Kow and Lustig 2018). The authors make use of the idea that incremental additions of fieldwork in multi-sited ethnography provide opportunities to report on new findings at relevant intervals. The way the authors describe their previous empirical work and publications in the field of Bitcoin brings credibility to the here reported relatively confined fieldwork of carrying out participant observation in two Bitcoin conferences held during one month. There are also other articles in the collection (e.g. Mikaelson et al. 2018; Ulriksen et al. 2017) that can be distinguished as multi-sited, i.e. the researchers have in some ways engaged in 'following' multiple traces of the infrastructuring phenomenon under study, so that investigation has been conducted at multiple locations/sites, with multiple study participants, tracing various documents as well as technologies, which the researchers have identified of relevance for their particular research interest in infrastructuring.

In contrast to the above-mentioned multi-sited studies, Grisot and Vassilakopoulou (2017) report on a longitudinal single-site study that was part of a large research program on the topic of interplay between new information technologies and existing modes of organizing in healthcare. The authors have selected 'the specialized government Agency authorized to implement national health policies and to ensure secure information flows in the health and care sector' as the key location for investigation, and they particularly focus on the multi-expertise team dedicated to the eDialogue initiative under investigation. The authors began by gathering and analyzing programmatic and strategic documents of the initiative with the purpose to gain an understanding of its background, context and motivation. This was followed by an intensive fieldwork period including observation of the team's weekly and thematic meetings and workshops and semi-

structured interviews to gain understanding of the unfolding changes. In single-sited investigations, it is important to attend to the more extended temporal and spatial scopes of infrastructuring. Therefore, the authors extended the scope of data gathering to the team's document repository and to interviewees beyond the team. Extending beyond the single site is often done through a recourse to interviewing and documents analysis, but other methods have also been suggested, such as 'scalar devices' (Ribes 2014).

Marttila and Botero's study design is based on reflexive analysis of two of the authors' previous projects in digital cultural heritage (2017). With a framing of 'commons' and discussion of the concepts of infrastructure and infrastructuring, the authors point out some differences between the cases but are more interested in reading the cases together in order to provide a broader view into the infrastructuring challenges for digital audiovisual cultural heritage. With two dissimilar enough cases, the authors gain leverage to more generally point to issues that they see as central to the emergence of cultural commons across time.

The article by Bødker et al. (2017) unfolds a narrative of a participatory design (PD) project in an educational setting to exemplify and discuss 'participatory infrastructuring'. The paper does conceptual work that draws from selected theoretical traditions and discusses with PD literature on infrastructuring, in addition to which it uses the case study to illustrate the conceptual understanding created. The paper describes a diverse set of PD activities on many organizational levels of political authority that revolved around technology, decision-making, competence-building, commitment, and policy-making within Danish educational system. Based on this, the authors put forward a compelling proposal for PD to expand in several ways, including extending the views on what constitute PD activities, the reach of infrastructuring across existing organizations as well as more temporary 'knotworks', and extending the 'vertical' arenas of political and practical involvement in order to include policy levels as part of infrastructuring. These suggestions align with recent calls for more reflexivity in PD research (e.g. Balka 2010; Karasti 2010), design fields to get involved with policy issues (Jackson et al. 2013, 2014), and existing research in other traditions actively studying infrastructures/infrastructuring (see e.g. Karasti et al. 2016). Methodologically this implies a requisite for increased mobility of the PD researcher, not only geographically, spatially and temporally but also capacities for 'intervening up' (cf. 'studying up') and new kind of interdisciplinary suppleness.

5.3. Two methodologically oriented articles

There are two articles with a specific methodological interest in the study of infrastructuring in the special issue. In the first one, Parmiggiani (2017) returns to the ethnographic investigation for her doctoral research (Parmiggiani 2015), adopts a self-revealing and self-reflexive narrative approach to report on her deliberate interest to reflect on the scales and political nature of fieldwork. She reflects back on how she constructed the field during her ethnographic work and how she shaped its dimensions with the combination of four scaling mechanisms inspired by common ethnographic practices that were particularly pertinent for her study context. Parmiggiani discusses how the process of constructing the field and recognizing it as a political arena, in retrospect, let her discover richer possibilities for understanding the politics involved in her study of infrastructuring. By paying attention to the constant re-work on the scales of design as part of the continuous political process relating to infrastructuring, both she and the study participants were involved in allowing voice to be given to specific, selected categories of human and non-human stakeholders.

In the second article motivated by a methodological interest, Karasti and Blomberg (2018) premise the methodological discussion by proposing a set of dimensions characterizing information infrastructures. These dimensions build on Star and Ruhleder's (1994, 1996) definitional work by drawing on recent research on (information) infrastructures and infrastructuring. The authors argue that for studying a phenomenon as heterogeneous, extended and complex as the dimensions they describe, researchers need to pay attention to how they make decisions during fieldwork and hence create various inclusions and exclusions. The notion of 'constructing the field' is key (Amit 2000; Blomberg and Karasti 2013; Karasti and Blomberg 2018) as it brings forth considerations of how the researcher conceives and constructs the field together with forming the object of inquiry during empirical engagement. Karasti and Blomberg urge to challenge the ideas of spatial trope and taken-for-granted boundaries, and offer alternatives for studying infrastructuring, such as how to conceptualize the field, invert infrastructural relations, follow connections, discover discontinuities, and extend and reflexively bound the field. These methodological issues are densely tied with problematizing assumptions of information infrastructures as stable, bounded and coherent, as well as examining issues relating to the extent, emergence and partiality of the object of inquiry in studies of infrastructuring. Karasti and Blomberg encourage researchers, not only ethnographers but more widely researchers grappling with how to study and design for infrastructures and infrastructuring, to engage with the field as constructed because it both helps to explore the ontology of infrastructures and gives rise to creative designs of infrastructures in increasingly connected yet fragmented environments.

5.4. Methodological issues across the collection

Looking at the collection of articles in the special issue through the lens of the methodological considerations put forward by Karasti and Blomberg (2018), we find that the articles typically list the empirical methods and the sites of inquiry where they have been applied. Rarely are there more elaborate accounts, for instance about how the sites were decided, subjects found, and documents identified as relevant. Few of the papers make an attempt to explain how the empirical field was constructed, a notable exception is the article by Parmiggiani that provides retrospective reflections on how she created the field in her research (2017). However, for most studies, the reader can gather some hints about the empirical field through descriptions of the methods and sites of inquiry, and in some articles, the reader can find some reflections about the empirical context, such as in Bødker et al. (2017) where the authors make a specific point about including 'unconventional back-stage PD activities', engaging 'a wider set of stakeholders', and focusing 'on the longitudinal network of activities' in participatory infrastructuring. Furthermore, the articles impart a rather uniform understanding of the field as related to the spatial/organizational trope. While some researchers make use of archived online discussions as sources of data (Ulriksen et al. 2017) or social media interactions to create rapport with the study participants (Parmiggiani 2017), only one of the articles uses Facebook data as a central resource for analysis (Menéndez-Blanco et al. 2017). However, even in the latter case the empirical site is understood more in spatial terms, rather than online, virtual, or created via co-presence. All in all, explicit reflection on choices made, other than in terms of adjusting the scope of data collection and analysis to address the specified research topic, is frequently missing. Thus, it often remains implicit, unarticulated and unproblematized how the studies are 'put together' empirically.

One of the themes that runs across the articles in the collection is 'scope and reach' and 'scaling', thus continuing addressing the theme of extending the scopes in investigating infrastructuring

(Pollock and Williams 2010; Karasti et al. 2010; Monteiro et al. 2013; Blomberg and Karasti 2013). While the empirical infrastructuring phenomena are often conceived of as extended, for studying them researchers commonly use entry points at a smaller scale of analysis. The articles typically address 'scope and reach' by extending the investigation in spatial, organizational and/or temporal terms. Many studies use interviewing and document analysis that allow for reaching beyond the here and now of observation, both temporally and spatially; the study designs in several articles are multi-sited; and many studies engage in fieldwork and empirically grounded design activities over extended time periods, some over several years. While many of the articles take the boundaries of the infrastructuring phenomenon as in some sense given or bounded, for instance, by the organizational entities being studied, there are also examples that display an understanding of infrastructuring as unbounded and emergent. For instance, Parmiggiani perceives the 'scales of infrastructuring' as continuously changing (2017). Bødker et al. discuss participatory infrastructuring by addressing both the fluid and temporary 'knotworks' and navigating the more permanent authority 'structures' (2017). Karasti and Blomberg, by putting forward the dimensions of 'relational' and 'connected' as well as 'emerging and accruing', emphasize the need for the researcher to continuously construct the field as the phenomenon is 'pursued' so that it is possible to address both 'continuity and change – the stable and emerging forms of infrastructures, all the while keeping relevant both variability and consistency' (2018).

Furthermore, the articles in these special issues represent either the work of one researcher, or a relatively small group of scholars engaged in a project. With Kow and Lustig (2018), however, we get a glimpse of the larger project that examines Bitcoin activities globally in which the authors conducted their research. The collection does not include examples of the more extensive team-based and multi-sited investigations that may be necessary in order to scale up infrastructuring studies and more extensively explore their ramifications across time and space as Edwards et al. (2013) encourage. Therefore, we may expect new methodological forms to emerge for the study of infrastructuring.

6. Design Issues Across the Collection

One of the most exciting aspects of the 'infrastructuring' perspective is that it allows for a fresh view on design activities (in the widest sense of creative activities intended to provide a lasting improvement to the technological support for a practice) beyond well-established structures of professionalization, and associated process models and technology development methods. These structures have well-established audiences among technology development practitioners, and cater to their work organization needs. While the long history of software engineering, requirements engineering and user-centered design allows to detect a trend towards giving more and more attention to matters of the practices that a technology is aiming to support, those methods may involve, but not necessarily inform practitioners beyond the technology development sphere.

Participatory design methods make a distinctive effort not to leave decision-making power in the hands of developers, but to allow practitioners of the application domain to have a say in conceptualization and implementation questions related to a technology aimed to support their practice. The resulting discourse has developed different shades of methodological formality, from approaches that aim to serve as alternatives to software engineering methods, to approaches treating participatory design as a (technology development) practice that benefits from fostering knowledge sharing among stakeholders in particular practice domains, but not necessarily from a

strong abstract methodological conceptualization that again would be likely to cater to only a subset of practitioners involved. Relying on simple descriptions of practical experiences (for example, in the form of case studies) again may not be enough to provide a discursive form that permits the consolidation and alignment of good practices. The discourse that has emerged around infrastructuring may help us here to find a language and conceptualization that may help guide collaborative design activities in a less technocentric way.

This discourse developed first as an analytical practice from science and technology studies that very carefully placed the various actors involved with or being affected by the development of technological infrastructures on maps documenting planned, targeted development efforts as well as emerging phenomena of appropriation, standardization, regulation, policy making and so forth. In so doing, the infrastructuring perspective established a relational notion beyond what a technological infrastructure is, to what it means to the actors involved and how this meaning emerges for individuals as well as among groups of actors.

We now consider these activities of mutually shaping the relation between a technological infrastructure and the practices it supports as collaborative design activities in a wider sense. It allows us to reflect on the conceptualizations established by researchers to assess their value for informing collaborative design methodologically. We now revisit the articles published in our special issues to draw together some observations of and impulses to inform collaborative design.

Crabu and Magaudda (2018) present a study that suggests that stakeholders involved in creative and constructive activities around developing an infrastructure refer to technological devices not only as a functional part of the infrastructure they use. It is a substantive example of how technological devices (in this case antennas helping to provide internet access) serve as anchors for identity and sense of ownership as well as constitute concrete objects a collaboration develops around. This study can be taken as a further argument to suggest designing not towards a technological product or functionality, but towards establishing relations between infrastructural entities and human actors. While using this infrastructure to connect to the internet can be considered a most mundane relation for infrastructuring work, it turns out that issues of maintaining the antennas and promoting the installation of new antennas to improve or extend the network created more complex relations, which collaborative design methods should aim to inform.

Kow and Lustig (2018) present an interesting counterpoint to this approach in their study of infrastructuring Bitcoin. Contrary to Crabu and Magaudda (2017) the study documents infrastructuring efforts in an arena where the precise functional aspects of an infrastructure are subject to emerging or unknown framing conditions to an extent that requires continuous sense-making activities among the actors involved. The authors' deployment of Neumann and Star's (1996) concept of an imaginary as a narrative that signifies an understanding of potentialities of the emerging infrastructure could also become an interesting concept for informing design methods. While imaginaries are consolidated narratives reflecting the perspective of an identifiable subgroup of actors (a document of coherence), they also become negotiable artefacts (a document of diversity as well as a resource for mutual alignment). The idea of describing an infrastructuring effort as a continuous process of creating imaginaries and engaging in crystallization processes to understand and overcome differences that became visible through imaginaries can also be used to suggest design methods that focus on these dynamics.

6.1. Anchoring design in processual aspects of infrastructuring

As a practice evolves through confirming/strengthening or questioning/weakening existing ways of doing, infrastructuring can be considered a continuous effort to reflect and negotiate a practice's infrastructural dependencies. The continuity is a theoretical one, as practitioner attention to infrastructural matters does not stay as focused all the time. It drops as infrastructures sink into the background, and it returns in the case of a breakdown. In a continuum, the breakdown marks an initiation point that remains tangible for owners of an infrastructure as well as the practitioners that depend on it. In Pipek and Wulf (2009) this was discussed as a potential 'point of infrastructuring' that spawns collaborative creative activities; in this volume Mikaelson et al. (2018) also establish breakdowns as driving forces of an infrastructuring effort, and suggest a model of infrastructuring that assumes a value network (organizations and stakeholders that provide an infrastructure), a process organization (general agreements and ideas on how to proceed) and material artefacts as means of participation being the main ingredients of an infrastructuring effort. Correctional activities involve ambiguous repair with regard to these structures: value-network repair to involve further organizations to continue providing the service that creates value for infrastructure users, process repair to refine the process models that give stakeholders an orientation for where the process is heading to, and participation repair to change the material foundations for user participation in infrastructuring.

6.2. The role of data in the mutual shaping of infrastructure and practice

The goal of an infrastructuring effort is usually to achieve some kind of change to an existing practice through changing the infrastructure the practice relies on. For the case of infrastructures involving IT, the abstractions of reality that allow for a support through computational services (the data structures and values that feed the IT systems involved) very often become political, and thus a part of an infrastructuring effort that requires explicit attention. There are few arenas where dealing with the data is already an explicit part of a practice, e.g. in scientific environments. Young and Lutters (2017) describe a case study where infrastructuring as a collaborative design effort targeting an infrastructure and a dependent practice comes full circle. It illustrates the generative power of breakdowns (or points of infrastructure – Pipek and Wulf 2009) in dealing with data structures to motivate an 'infrastructural inversion' of the information infrastructure to result not only in the new GLOBE information infrastructure, but also, innovatively, in a new practice called 'Land System Science' that is paradigmatically different from previous scientific fields. While the former can be considered a 'mundane' infrastructure improvement the latter illustrates that the dependencies that drive an infrastructuring effort may well motivate a new and ongoing practice of attending to issues around infrastructural dependencies of scientific practices, as a continued 'infrastructure inversion' and conscious handling of 'points of infrastructure'. Along similar lines, Ulriksen et al.'s (2017) study of the development of an Electronic Patient Record system in Norway works with 'archetypes' to make data structures tangible at the national (for standardization) and the local (for practice fit) level. These archetypes became the central artefactual category to be designed, discussed and negotiated to further develop the standardization and infrastructure, and - although domain specific in its concrete form - archetypes can represent in interesting and productive ways non-technological issues that large-scale infrastructuring efforts need to remain focused on.

6.3. Minding the stakeholders

When we discuss collaborative design in the context of infrastructuring efforts, stakeholder involvement and finding, connecting or providing arenas of collaboration is an ongoing task to foster infrastructuring. Menéndez-Blanco et al. (2017) provide a study of using existing social media for this purpose, as particularly Facebook has grown to become a platform where many potential stakeholders can be connected. In order to create or enhance 'publics' on dyslexia, they successfully used Facebook to generate awareness on the topic, but also point out difficulties that the platform infrastructure caused for understanding exact reach, scope and structure of the participants found there. As a practical tool in collaborative design, social media can help, but more specific tools are needed as well. Lindley et al. (2017) point out that the abstraction of reality into models, data structures and the data itself also brings the problem with it that the material framing of an infrastructuring process may get lost, resulting in fluctuating participations of stakeholders. As a counterbalancing initiative, they experimented with on-location voting machines as mechanisms to materialize the infrastructuring effort at relevant places, making space itself a foundation for material participation that may help keeping stakeholders involved. Marttila and Botero (2017) develop a different approach to connect the various stakeholders that need to participate in a process of creating cultural commons, freely available materials that document and potentially transfer historical and/or ongoing cultural practices. In a reflection on experiences from two European research projects they describe the use of two transitory concepts as tools for collaboration in design. The concept of an in-between infrastructure describes socio-material interventions and arrangements that enable experimentation among heterogeneous systems and with different actors. They serve as sites for rehearsing future practices. The concept of gateways (coined by Edwards et al. 2007) refers to assemblages and technologies that allow linking and bridging otherwise incompatible or disparate socio-technical infrastructures and practices. Gateways have been used as an analytical term, but Marttila and Botero (2017) document experiences of using the concept to identify sites and contexts of an infrastructuring effort (organizations, places, technologies) that are particularly appropriate to let in-between infrastructures demonstrate their mediation powers between until then separate fields of practice. While they nicely demonstrate the issues and concerns of this approach in the field of cultural heritage, the approach as such may serve as a targeted infrastructuring strategy to be initiated by stakeholders who aim to reach out to other relevant fields of practice. In their ambition of making a possible future infrastructure tangible, their approach resembles the pattern of developing imaginaries that resulted in the crystallization processes that Kow and Lustig (2018) sketched.

Bødker et al. (2017) report on experiences with 'knotworking' (Engeström et al. 1999) as a concept to develop workshops as arenas of multi-stakeholder interaction that do not target the big overarching issue or goal of an infrastructuring effort, but to rather rely on the sharing of abilities and resources of participants to temporarily stabilize and address shared concerns among the stakeholders involved in the workshop. The result that counts is not necessarily a solution to the partial challenge that led to the convocation of the workshop, but the emergence of mutual understanding and trust among practitioners connected to the same infrastructure. The authors used this concept at different scales of an infrastructuring effort to prepare Danish schools to host FabLabs (Laboratories for digital fabrication). The examples range from very concrete discussions of the cost and benefits at a Danish school to discussions on issues and concerns with regard to the introduction of this kind of institution into the Danish school system at a national, policy-oriented level. While the topics and participants of these workshops are changing and certainly

domain-dependent, the general strategy of addressing an infrastructuring effort by knotworking from the concrete, situational to the political might be fruitfully used in other domains.

Grisot and Vassilakopoulou (2017) aim to resolve stakeholder diversity in a different way. Based on their experiences from a study on the Norwegian healthcare system (unrelated to the site in Ulriksen et al. 2017) they suggest considering re-infrastructuring as a strategy that makes a conscious effort to leave functioning practices relying on an infrastructure untouched if a new practice connects to it or extends the infrastructure. A strategy like that would value continuity of practice as much as novelty, and aims at balancing these aspects.

6.4. Reading across the articles from the perspective of collaborative design

A very tangible result from this summary of the various contributions to our special issues from a 'collaborative design' perspective, is that there is an understanding emerging that separates traditional 'design' methods from approaches which guide stakeholders in infrastructuring efforts. This perspective aims at establishing Infrastructuring as a generative phenomenon, as a system of interwoven activities and performances that may benefit from a systematic reflection and resulting, clearly articulated suggestions for improving these activities, just as the development of design as a discipline provided a methodological framing for targeted creativity independent of the materials and tools that guided creativity in the salad days of artisanal craftsmanship. But infrastructuring is not design in a number of ways: there are no single 'visible hand', no clear material boundaries for either the process result or related factors, no clear locations of decision-making power, no coherent languages and terminologies and not necessarily shared perspectives among stakeholders about where the process is heading to and where they currently are. Where traditional approaches to technology development aim to identify and define roles, responsibilities and spheres of competency, infrastructuring can be seen as a method for guiding technology design needs to identify and inform possible translations and transitions between previously existing practices and infrastructures. We see a system of terminologies and approaches emerging from the work described here that aims to give stakeholders orientation and guidance in doing infrastructuring within this complex system.

The key is to reflect existing and potential technologies, but focus on addressing, describing, communicating and negotiating the relationships and dependencies the technologies bring with them when supporting a certain practice – while maintaining an understanding of a process of (further) developing socio-technological infrastructures. The resulting collaborations still use descriptions of technological structures, but they do not target them *per se*, but only through the network of dependencies they will maintain or produce.

A useful conceptual language is not that of technology, rather that of informed change. It does not privilege one of the practices involved over the others. It does acknowledge the variety of concepts that are local to the practices involved, and affords establishing a mutual transparency between these conceptual worlds. It aims to maintain an overview on processes of developing or changing infrastructural dependencies, but it assumes a position within the process - not above - understanding that any perspective on the process must be partial. We found many approaches and inspirations in this collection of articles.

This generative infrastructuring perspective may produce new sets of methods which go beyond traditional design: for example, it calls for frequent, systematic practitioner reflections on the

infrastructural dependencies of their practices, and it may suggest new technology interface designs that aim not only to deliver its functionality to its users, but prepare technological devices to become sites of infrastructuring, for example, by also representing and explaining hidden parts of the infrastructures they give access to, or by directly supporting communication, collaboration and configuration activities connected to an infrastructuring effort.

7. Challenges and Opportunities

With such a rich array of papers, it is hard to see beyond them in order to grasp what is missing in the field, and what the opportunities for future research may be. However, a few observations are in order.

First, it is extremely difficult to study infrastructure at the appropriate temporal scale. If we can take as a rule of thumb based on the printing press and the Internet for example, it takes 50 to 100 years for a new infrastructure to really develop (to move from being more gerund to noun; although that move is never complete). Research in our field has not yet envisaged truly long term qualitative research projects to complement long term quantitative studies - we do not know how to share information across multiple research projects and over time.

Second, related to this, it is generally clear that it's never about just one infrastructure. The model many work by is that infrastructures subsist in nested hierarchies – so that in order to study one, it's possible to ignore the others as 'background'. However they don't. A new infrastructural development jostles with others; working out on fly what will be beneath it in the stack and what will be above. To borrow terms from developmental biology: we have been very good at looking at organisms (individual infrastructures) and very bad at looking at ecologies.

Third, we have terrible metrics about what works and doesn't in an infrastructure. In cyberinfrastructure studies, the generic belief is that if no-one is using the infrastructure at the end of the day, then the whole effort was a failure. This is just wrong. We need to get beyond success/failure and explore what is really going on. Inspired by Gina Neff's (2012) work on Silicon Alley, one might think of people learning skills and lessons and going on to new infrastructural projects; one might think of them meeting people with whom they can collaborate synergistically in the future and so forth. Infrastructuring is never solely about product creation – it's about building sociotechnical networks, where there are no fixed entities: what it is to be a person, an organization and a technology are all up for grabs. We need to develop a new language for the ecology of outcomes of infrastructuring projects.

Fourth, it may be valuable for researchers in information infrastructures to attend to the 'infrastructural turn' in the field of anthropology – signaled by Larkin's majestic paper on the politics and poetics of infrastructure (Larkin 2013). The field of information infrastructure studies stemmed in part from the study of electricity networks by Thomas Hughes (1983), and it would be sad for this filiation to be lost.

Fifth, it is notable that a number of the papers used the concept of infrastructural inversion. This is perhaps one of those usefully flexible notions such as the rich, entrenched concept of 'boundary objects' (Star and Griesemer 1989), which can generate new kinds of discourses among communities in science and technology studies, CSCW and practitioners. While the articles in the special issues have been grounded in its initial analytic form (Bowker 1994), we can see in the

wider literature that there are also other ways of using the concept – including the ethnographic/empirical (Harvey et al. 2017) and the generative/designerly (Kaltenbrunner 2015; Parmiggiani 2015; Korn and Volda 2015). It is clear that we need to forge new bridges between analysis and design in order to account for and deal with the complexities of infrastructuring. Taking ‘infrastructuring’ seriously, the relationship between figure and ground – core to the concept – has to be at the fore. In geology, we have learned that organisms geo-engineer the world (think of the oxygen we breath and the soil we grow crops in): the world is not a passive backdrop against which action occurs. Similarly, through infrastructuring we learn that our practices change our technology as much as our technology changes our practices. We need a rich language to explore this.

Finally, we return to the gerund. These papers have collectively demonstrated that there is great analytic purchase to the concept of infrastructuring. We encourage and invite further contributions to this emergent domain.

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