Innovation in Information Infrastructures

Innovation in Information Infrastructures: Introduction to the Special Issue

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1. Introduction

Recent discussions in the information systems field have sought to improve the conceptualization of the IT artefact (e.g., the forthcoming 2014 *MISQ* special issue on sociomateriality or the *ISR* anniversary issue (volume 21, issue 4, 2010)). An important part of this discussion has been a convergence of interest among scholars from diverse fields around the concept of information infrastructures (IIs). Use of this terminology signals a shift of focus from discrete information systems towards evolving assemblages of interlinked systems. Thus Monteiro, Pollock, Hanseth, & Williams (2013, p. 576) offer the definition that:

IIs are characterised by openness to number and types of users (no fixed notion of "user"), interconnections of numerous modules/systems (i.e. multiplicity of purposes, agendas, strategies), dynamically evolving portfolios of (an ecosystem of) systems and shaped by an installed base of existing systems and practices (thus restricting the scope of design, as traditionally conceived). IIs are also typically stretched across space and time: they are shaped and used across many different locales and endure over long periods (decades rather than years).

By connecting a growing number of systems and data, IIs support user work in everyday life and bring about increased organizational and technological complexity. As IIs permeate an increasingly broad range of social and institutional contexts, they generate both new kinds of challenges for information systems development, and new social, organizational, and market forms as foci for social scientific investigation. Accordingly, our interest encompasses changes in the form and uses of IIs, and the changing ways in which IIs are created, implemented and maintained. The topic of innovation in IIs (III) has been covered before but only partially (e.g., special issues on social media or digital innovations), whereas we promote a more comprehensive account.

The present issue draws on an international research workshop on III hosted at the University of Edinburgh (held on 9-11 October 2012). The workshop attracted over 80 participants who presented 32 papers. The workshop acted as an important venue for potential contributors to this special issue to meet, discuss, and be challenged.

The 2012 III Edinburgh workshop built on analytical developments in a previous *JAIS* special issue on information infrastructures (volume 10, issue 5, 2009) that emerged from the alignment of interest among European and American scholars who serendipitously organized research workshops around converging intellectual agendas. A research community has been developing. It has drawn in contributions from Information Systems and from colleagues in the field of Computer Supported Cooperative Work, from Science and Technology Studies, and from other cognate fields including Organization Studies. Discussion has continued through various channels (recent initiatives include, for example, a Danish conference series on infrastructures for healthcare, which resulted in a special edition of *Computer Supported Cooperative Work* (volume 19, no 6, 2010) and a forthcoming special edition of the *Scandinavian Journal of IS*), a track on inter-organizational systems, information infrastructures and innovation dynamics at the 21st European Conference on Information Systems (5-8 June 2013)) and has inspired a wave of research that seeks to apply and develop the II research agenda. This special issue reflects the vibrancy of this emerging informal research program that today addresses a wide spectrum of empirical domains. From the outset, healthcare has been one of the main instances, given the scale of IT investments, the challenges surrounding health IIs in terms of the complexity of functions, number and range of users, and their increasing centrality to health service delivery. But now, we have seen II perspectives applied to various other domains (e.g., finance, energy, and e-science) and to both developing and developed countries. Our interest in innovation in IIs encompasses the processes through which IIs are created, implemented, maintained and used; the dynamism or obduracy of their innovation and how this may be patterned by the context and socio-material form of IIs, and may evolve over time.

2. This Issue

This SI signals an important shift. In the first generation of II research, scholars focused on how to conceptualize IIs. Some scholars attempted to go beyond previous ways of conceptualizing that tended toward dichotomies between (particularly) the local and the global, and/or between system design and implementation/use. The 2009 *JAIS* special issue on IIs began the process of developing a new language and analytical schema for understanding IIs. It flagged the ways in which infrastructure building initiatives needed to simultaneously address multiple locales, phases, and timescales—both the ‘here and now’ and the longer-term evolution of the system. Across various contributions, there was a shift from characterizing infrastructures as objects (noun) toward a more processual focus on that addressed the practices of building (designing, implementing, using, further developing) infrastructures: **infrastructuring** (verb) (Pipek & Wulf, 2009)

This special edition (spread over two issues) brings together contributions from the second generation of infrastructure studies. It reports on research conducted in an II perspective. II studies have, arguably, “come of age” in a number of ways. First, we note how the papers in this special edition arose from extended studies that go beyond snapshots of particular moments of II development/evolution to engage with multiple moments and longer-term trends, that could be seen as responding to calls to address the “biography” of II artifacts and practices (Pollock & Williams, 2010).Second, the close focus on practice and intimate relationships with practitioners (developers and users) afforded by these detailed ethnographic studies offers particularly rich insights. The SI explores the theoretical, methodological, and practical insights that are foregrounded if an II perspective is employed as a tool for analysis and, to an increasing extent, as a guideline for intervention. The emerging practices of II development are becoming more elaborate. Today, we find that the ecology of players, services, software, and platforms enabled by network connectivity and contemporary tools is increasingly complex. Information infrastructure standards and patterns of usage have been established, which has legitimized a growing set of user strategies, social competences, and forms of expertise. Finally, we note the growing body of empirical studies of II innovation, which provides a base for a more systematic exploration of how the challenges of II development may vary across contrasting socio-technical settings.

We now briefly review each of the six papers in this special edition before examining some of the cross-cutting themes and issues that they raise.

The first paper, “Generification by translation: designing generic systems in context of the local” by Line Silsand and Gunnar Ellingsen, contributes to the under-researched area of the design and development of generic systems (a large-scale electronic patient record (EPR) system) and represents one of very few studies of the early stages of such developments. In this case, the vendor had chosen to use “agile” development methodologies—methods widely adopted to involve users in iterative development of systems that match their specific needs—to develop a generic EPR solution. The paper highlights a contradiction surrounding this endeavor between, on the one hand, the need for close vendor-user links to capture specific user requirements and practices, and, on the other, the need for the developer to stand back from particular users to develop a generic solution. What began as a lightweight development process gave way to “heavier” upfront design as designers struggled to translate context-specific information (arising, for example, from user stories) into a more abstract form that could inform the design of the customizable components of the system and meet demands arising from the international openEHR framework. It proved equally challenging to engage users in discussing functionality that was not relevant to their immediate contexts.

The paper focuses on communications between users and developers, which, in traditional agile development, revolves around their circulation of “user stories” and experimental artifacts. In this case, the paper reveals the ways in which developers needed to obtain broader contextual information about use

practices. It draws implications for how we can organize this engagement more effectively by supporting developers to communicate software concepts and give users skills in communicating contextual features of their work.

The second paper, “Innovation of, in, on infrastructures: articulating the role of architecture in information infrastructure evolution” by Miria Grisot, Ole Hanseth, and Anne Thorseng develops an information infrastructure perspective on medical health records. In presenting a longitudinal and evolutionary case study of a Norwegian medical health record project, it argues for a “cultivation”-based approach to understanding the bottom-up development of IIs. Detailed insights into the distinctive cultivation strategy adopted in this case are explored through looking at three different episodes of II development/innovation that occur within this project over time. These involve respectively: **innovation of** the infrastructure; subsequent **innovations in** components without changing the constituting architecture; and, finally, innovations of applications running **on** this platform (reflected in the title: innovation, **of**, **in**, **on** infrastructure). The authors emphasize the importance of “experimental development”, the “flexibility” of solutions, and the possibility for further innovation on IIs as users’ needs develop and change over time.

The third paper, “Grafting: balancing control and cultivation in information infrastructure innovation” by Terje Sanner, Tiwonge Manda, and Petter Nielsen, draws from the horticultural idea of grafting to understand how elements (practices) become incorporated into evolving information infrastructures. Indeed, though the concept of information infrastructures revolves around the idea of an extending heterogeneous system of systems (which necessarily involves elements developed at different times and places), there has been a lack of concrete analysis of how these elements are combined and carried forwards (or not). In their grafting concept, the authors build on an earlier idea of growing infrastructures by cultivating an installed base (Bergqvist & Dahlberg, 1999; Aanestad & Jensen, 2011). Though aware of the risks of adopting biological metaphors, the authors find new insights, in particular regarding “congeniality”—the ability of a new component to integrate, adapt, adjust, and coevolve with the evolving infrastructure.

The authors empirically explore these processes in the context of health information systems in Malawi, in which, where internet connections are lacking, mobile phones are used to transmit data between local health professions and central health administration. In this way, the paper contributes to our understanding of how information infrastructures are constructed in technologically “sparse” contexts.

The fourth paper, “Innovating financial information infrastructures: the transition of legacy assets to the securitization market” by Antonios Kaniadakis and Panos Constantinides, gives a fascinating and rare insight into largely invisible or black-boxed aspects of finance. Drawing on fairly unique empirical data from a U.K. bank, the authors examine how a novel II was constructed to allow UK banks to raise money through securitization. Securitization was a financial innovation adopted from the US, whereby the

assessment of credibility (and thus financial risk) was shifted from the intrinsic qualities of an asset to pre-defined financial data and scores provided by rating agencies. Securitization, in short, represents an interesting and important example of an (attempted) quantification of quality. By separating data validation from established risk calculation processes within the bank, Kaniadakis and Constantinides frame risk calculations as “uniform materialities that can be measured and calculated by other agents, potentially in other contexts” (Kaniadakis & Constantinides, 2014), which would allow banks to raise money by trading risks on credit market.

In the UK, securitization needed to accommodate the significant “installed base” of legacy mortgages. The focus in Kaniadakis and Constantinides’ paper is on the practices and technologies—the information infrastructure—implicated in realizing the transition to securitization. So much more than merely an idea, securitization involved the meshing with existing practices and tools, and devising new ones (e.g., new modes of data validation).

The fifth paper, “Flexibility relative to what? Change to research infrastructure” by David Ribes, provides a vivid and rich account of a long-term research network on HIV called MACS. Effectively challenging the working definition of II underpinning this special issue, the paper weaves together what Ribes dubs the technoscientific, sociotechnical, and institutional changes in and around MACS throughout its thirty years of history. It is accordingly a “corrective”, in Ribes’ words, to the dominance of the narrower sociotechnical approaches prevailing in II studies to date. His analysis encompases the way scientific practices (methods and instruments), design/user interactions, and funding and regulatory environment (institutional) dynamics mesh and are mirrored in the evolving research network enabling an interesting explanation of “what”, “when”, and “why” elements of the research network change. The paper leans on the stream of work on e-science, a research stream intimately tied up with the work on IIs.

The paper provides a compelling history of how practices, tools, and protocols embedded in MACS constantly evolved by shedding some parts and adding others. Ribes uses this large canvass of change and stability to develop an analysis of “flexibility”—a notoriously slippery notion. He offers a non-essentialist, relativist understanding of the term. Flexibility, in contrast to dominant accounts, is not characterized by a set of attributes of the information system(s), but rather emerges as the *ex-post* result of a process. Drawing on the central argument that flexibility is not a property but a capacity that can only be assessed in relation to particular instances of change, Ribes spells out an agenda for future research into how flexibility is realised in different settings.

The sixth paper, “Situated with infrastructures: Interactivity and entanglement in sensor data interpretation” by Petter Almklov, Thomas Østerlie and Torgeir Haavik, makes a unique contribution through revisiting the concept of “situated action”, focusing particularly on recent discussions of this term and how it has been adapted and critiqued in light of contemporary developments in ICTs. It specifically investigates how the notion of situated action might be

understood in a study that gives information infrastructures central attention. Empirically, the paper describes the work of petroleum engineers and how they interpret subsurface data. Rather than question the appropriateness of the notion of situatedness, the paper argues that researchers should focus on how information infrastructures extend or, to use their term, “stretch” local settings such that actors are able to interact—and make sense of data from—across space.

Various interesting and challenging themes run through this collection of six papers, some of which we identify below.

3. Themes and Issues

3.1. Analyzing the Dynamics of II Development and Evolution

As we noted in Section 2 above, much of the work reported here arises from long-term studies that have tracked, often in real-time, the processes of II development and evolution. This research offers a more effective understanding than can be achieved either through retrospective study or through the shorter-term studies of particular moments (e.g., of technology development, adoption, or use) that prevail in our field, conditioned in part by the typical time and resource constraints of current research funding models (Pollock & Williams, 2010). It allows us to explore the complex dynamics of III and the coupling between design/development episodes and longer-term evolution. This is a particular feature of the three studies published here that report on health II development and evolution, which carry analysis forwards beyond particular moments and sites. Thus, Silsand and Ellingsen (2014) focus on a nexus of II design and development and how specific user knowledge becomes translated into the design of generic infrastructure components. Grisot et al. (2014) explore how the particular cultivation strategies adopted by the health II developer they study has allowed a surprising level of flexibility and creativity in II development to be sustained, in parallel with the wider roll out and implementation of this functionality. This contrasts with frequent experience that innovation in development may be hard to combine with roll out. It holds out the prospect of continued innovation in the II as user requirements and contexts evolve. Sanner et al. (2014) develop a conceptual schema and an empirical case to explore how novel elements may become incorporated (grafted) into an II and whether they prove congenial and are sustained.

3.2. II Innovation as a Relational Property and a Strategic Achievement

The growing body of II studies provides a knowledge base for comparative analysis that draws our attention both to IIs’ potential intractability and potential vulnerability (Ciborra et al., 2000). It also includes cases in which remarkable fluidity and generativity have been sustained. These studies, on the one hand, alert us to the uneven challenges surrounding II innovation in different settings and how they may vary, for example, according to the

number and range of users and uses and the associated coordination challenges in II development. On the other hand, they draw attention to the success of some II builders in navigating around these constraints. We are aided here by the availability of detailed studies on II innovation dynamics, which also afford insights into the strategies adopted by II builders.

Here we are able to identify a number of intervention strategies that have proved effective, for example, in enabling systems to be designed and redesigned around evolving user needs. Grisot and Hanseth (2014) in particular draw our attention to the reciprocal relationship between II architecture and the ways in which II innovation is organized, and to the specific features of the architecture and associated development strategy in their case which enabled creativity and experimentation to be sustained. This introduces the issue that is at the heart of Ribes' paper: that examines how the MACS research project has sustained itself over an extended period despite profound changes in its role and challenges. Its remarkable "flexibility" is not an inherent property but the outcome, in the face of particular changes and challenges, of particular technical and organizational forms and multiple strategies geared towards adaptability, robustness, and extensibility and other facets of flexibility.

3.3. Knowledge Infrastructures—How Knowledge is Integrated and Made Mobile

Three papers share a central concern with the role of IIs as "knowledge infrastructures" (Edwards *et al.* 2013). Across very different settings (an AIDS research project, the oil extraction industry, and the finance sector), we find increasingly elaborate Internet-based IIs playing an ever more central role in the "epistemic machinery", with complex implications for ways in which knowledge is generated, transformed, made available (increasingly in the form of online data), and consumed.

Thus, Almklov et al. (2014) analyze the efforts of engineers in the oil industry to make sense of what is happening below the seabed through combining data from various imperfect sensors. They remind us that knowledge production is what Suchman (1987) describes as a highly situated activity. They highlight the tools and practices that allow different kinds of data to be integrated. However, these emerging IIs make it possible for knowledge to become more mobile (e.g., allowing the work of interpreting this data to be shifted onshore). Mobility, however, has complex effects: as IIs extend across and between organizations, access to the information generated moves beyond the actors who are directly involved in the process of its production (who are aware of particular methods and circumstances of its creation, its affordances, and the certainty/circumstances under which it provides a reliable indicator of the phenomenon being assessed). What happens when contingent knowledge is made readily available to other groups? What may be lost in terms of awareness of the contingency and fragility of particular interpretations. This draws our attention first to how interpretations that might be contested and contingent acquire the facticity of data, data that are amenable to wider circulation, aggregation, and processing through IIs. Second, how may this processed information acquire authority and become the basis of other kinds of activity (e.g., decisions about where to drill for oil).

Kaniadakis and Constantinides (2014) explore how financial IIs set in motion a chain of calculation and data validation whereby the risks surrounding diverse assets come to be framed as uniformly calculable and thus form the basis for trading in risk. In both of these respects, the underpinning question remains about what happens when the relationship between the data and the situation being monitored breaks down and the fragility of the processes of production and interpretation of data are brought to the surface.

4. Looking ahead

We suggested in Section 2, that this special edition may point to the "coming of age" of II studies. What next, then? Assessing what is covered and the blind spots, we see a further stage in the development of enquiry into IIs to address a set of related themes and issues. We highlight some of these below:

- Building upon the growing body of II studies we identify the need and opportunity to systematically explore how the challenges of II development vary across contrasting socio-technical settings with their different coordination challenges, scale, number and range of users, institutional settings, and resource availability.

- Here, a key parameter that we have touched on but that deserves further analysis appears to involve levels of sensitivity to failure: the criticality of activities supported and the extent to which the II is tightly coupled to these activities. Innovating IIs in healthcare delivery seems to pose particular challenges (Hyysalo, 2010). This contrasts, for example, to the fluidity of II development we have observed in research settings.

- Linked to the preceding points, we note a need and opportunity to interrogate further how the innovation and evolution of IIs may vary according to the different socio-technical constitution of IIs. While IIs are hybrid assemblages of machine and human components, the relative contributions of each and the manner in which they are combined varies. Sanner et al.'s (2014) paper highlights the ways in which users remedy gaps in the technical infrastructure by drawing on other communication systems and practices. This study may be indicative of the II building strategies in the technologically sparse contexts of developing countries. Further research would be welcome.

- At the opposite end of the spectrum, how do the II challenges and opportunities change as we move towards a situation characterized by the availability of a multiplicity of (nested) platforms? Sawyer, Wigand, and Crowston (Forthcoming) draw attention to the information assemblages that may be put together by professional groups and organizations. Similarly, Carroll (2006) discusses how individuals constitute "personal information infrastructures". These, in turn, draw attention to the ways in which "end users" with limited technical resources may together "configure" (Fleck, 1988) an array of off-the-shelf services and device to produce solutions matched to their particular needs and practices (as evinced by the ways in which academic researchers—like many other peripatetic knowledge workers—ensure dependable access to information resources required when working away from their offices by carrying with them multiple means of accessing

computing power and their data). This points to new kinds of fluidity that may become available (information infrastructures 2.0?) and new modes of development (infrastructuring as configuration).

- Following on from the previous point, what will be the interplay between these emerging "lighter" forms of II in comparison to the traditional "heavier" forms? Under which context do one or the other prevail?

- We may anticipate that these choices may be heavily shaped by the institutional context (e.g., what is at stake in the information being transacted, ownership and control, the (inter-) organizational context, whether it is regulated (e.g., for privacy or commercial reasons)). To date, there has been little systematic consideration of the influence of this broader context on the form and dynamics of III – even though such an assessment would have immediate implications for II policies. This would be an important supplement to the work started by this SI that examines what scope exists for proactive II interventions, policy, and governance—and how these may vary under different II forms and settings.

We conclude that, although significant headway for II studies has been made to date (including the valuable work reported here), there remains substantial un- or poorly charted terrain and new developments and issues that call for further scholarly work.

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