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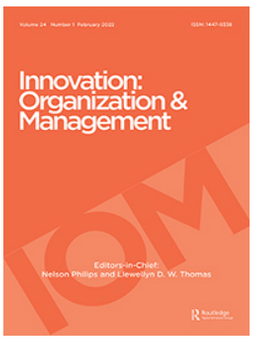

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ESSAY

Digital innovation: transforming research and practice

Marcel L. A. M. Bogers[a,b,c], Raghu Garud[d], Llewellyn D. W. Thomas[e], Philipp Tuertscher[f] and Youngjin Yoo[g]

[a]Industrial Engineering and Innovation Science, Eindhoven University of Technology, Eindhoven, Netherlands; [b]Department of Food and Resource Economics, University of Copenhagen, Copenhagen, Denmark; [c]Haas School of Business, University of California, Berkeley, Berkeley, CA, USA; [d]Smeal College of Business, Pennsylvania State University, State College, PA, USA; [e]Information Systems Department, IESE Business School, Barcelona, Spain; [f]School of Business and Economics, Knowledge, Information and Innovation, Vrije Universiteit Amsterdam Amsterdam, Netherlands; [g]Weatherhead School of Management, Case Western Reserve University, Cleveland, OH, USA

ABSTRACT

There is no doubt that digital technologies are spawning ongoing innovation across most if not all sectors of the economy and society. In this essay, we take stock of the characteristics of digital technologies that give rise to this new reality and introduce the papers in this special issue. In addition, we also highlight the unprecedent opportunities that digital innovation provides to study innovation processes more generally. Overall, we conclude that the speed, observability, and relative ease in investigating relationships between multiple analytical levels, mean that digital innovation is both a 'model of' that also provides a 'model for' the study of innovation processes more broadly in non-digital and hybrid contexts.

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Since the turn of the millennium, the pervasive adoption of digital technologies and the implementation of digitally enabled infrastructures have fundamentally changed the nature of products and services across most if not all industries. Recent advances in digital technologies (e.g., mobile computing, artificial intelligence, blockchain, virtual and augmented reality, robotics, the Internet of Things, and 3D printing) are fostering dramatic changes in the economy and organisations. A significant driver of these changes is digital innovation, which has been defined as 'the creation of (and consequent change in) market offerings, business processes, or models that result from the use of digital technology' (Nambisan et al., 2017, p. 224).

Digital innovations are changing the ways products and services are developed, produced and used. For instance, innovations using digital technologies enable the 'sharing' of inputs or resources, such as cars, tools, and accommodation. Such innovations are disrupting traditional markets, including media and entertainment, automotive rental and sales, hotels and hospitality, and even temporary labour markets. As digital

CONTACT Llewellyn D. W. Thomas admin@albistur.com

innovation proliferates, there is an increasing array of digital artefacts, which themselves present more opportunities for digitisation and digitalisation (Gradillas & Thomas, 2021). Underpinning this proliferation is the fact that digital products and services continue evolving by gaining new functionality through updates or novel connections with complementary products and services (Yoo et al., 2012). In other words, they are 'incomplete by design' (Garud et al., 2008).

While offering unprecedented opportunities to incumbents and new entrants, the development of new digital products and services presents significant management challenges (Nambisan et al., 2017). For instance, the combination of hardware and software that make up digital technologies generates peculiar features such as 'convergence' (Lee et al., 2010; Sick et al., 2019) and 'generativity' (Thomas & Tee, 2021; Zittrain, 2006), which go beyond what is possible with traditional technologies (Yoo et al., 2012). While convergence creates challenges in understanding the emerging interdependencies in previously discrete industries, generativity results in challenges of control as the innovation enabled by digital technology is virtually unconstrained.

Challenges also arise as digital technologies not only allow new products and services, but also enable new ways to organise and the potential for new business model innovations (Sund et al., 2021), some of which are disruptive. For example, by offering actors novel ways to connect through platforms, digital technologies have enabled the emergence of peer-to-peer marketplaces (e.g., Airbnb) and made it possible for B2B lease and rental actors to push for B2C markets. Moreover, due to its characteristics, digital innovation poses a challenge for incumbent firms whose responses can shape industry structure. For instance, in this special issue, Vaskelainen et al. (2021) show that incumbent companies often fail to actively exploit the opportunities enabled by digital innovation. Because many digital innovations require fundamentally different capabilities, many incumbents depend on their collaboration with partners who already possess those capabilities, thereby inducing a change in industry structure. Thus, understanding the emergent opportunities, design criteria, commercialisation challenges, market and industry impacts, and strategic responses to such business model innovation represents a significant managerial challenge.

Additional challenges arise through the ability to encapsulate material technologies with information, making it possible for digitally enabled products to connect with one another in multiplexed ways (Tilson et al., 2010). For instance, by dissociating the material flow of goods and services from the flow of associated information (Evans & Wurster, 1997), along with newly available analytics and insight, there is potential for greater control over material flows and activities. However, while these affordances open up possibilities for new business models, it is a non-trivial task to build the relevant capabilities to harness these constantly emerging opportunities that greater interconnection between digital artefacts entails.

Challenges also arise from the characteristic layered modular architecture of digital technologies (Yoo et al., 2010; Legenvre et al., 2021). For instance, the development of modules within and across layers typically transcends organisational boundaries. Consequently, rather than think of products and services as standalone offerings, it is imperative to also consider them as a part of platforms and ecosystems (cf. Clements et al., 2021). Developing platforms and ecosystems along with products and services adds complexity to the innovation process, which is challenging to manage (Cennamo &

Santaló, 2019; Hilbolling et al., 2020), adding risk that managers are often ill-equipped to address (Adner & Feiler, 2019). Furthermore, the emergence of a layered modular architecture means that innovation activities can be focused on a particular horizontal layer that can cut across multiple verticals (Henfridsson et al., 2018), rather than the traditional focus on a particular industry vertical or adjacent verticals, adding additional complexity.

Moreover, the different layers of the modular architecture develop at different rates. Consequently, innovation in one layer can impact technologies in other layers (including material ones) even after being launched. Not surprisingly, the evolutionary processes surrounding digital technologies are different from those documented for traditional technologies. Specifically, innovation processes involving digital technologies may not follow the typical two-stage evolutionary pattern with eras of ferment and incremental innovation separated by the emergence of dominant design (Anderson & Tushman, 1990). Instead, the presence of digital components adds ongoing evolution and transformation (Garud et al., 2008; Yoo et al., 2012), which is not present in traditional product structures (Lee & Berente, 2012; Nylén & Holmström, 2015).

These observations have implications for theory and practice. For theory, we must go beyond the Schumpeter-inspired two-stage dominant design model. Instead, we need a model that conceptualises innovation as continuously ongoing. Usher's (1929/1954) process of 'cumulative synthesis' is one such model. Although Usher developed his model by studying mechanical inventions, his model explains a more generic process wherein inventions arise through 'the constructive assimilation of preexisting elements into new synthesis, new patterns, or new configurations of behavior . . . by establishing relationships that did not previously exist' (Usher, 1929/1954, p. 11). This process of cumulative synthesis is ongoing, without a beginning or an end. To establish this point, Usher cites Ogden (1926, p. 126): ' . . . in the mesh of continuous happening, in which different strands are consistently overlapping, it is often difficult, if not impossible, to determine either an absolute beginning or a finite end . . . '.

Usher's model has implications for practice as well. A key issue for Usher is the 'setting of a stage', by which he means assembling the various ingredients that can lead to 'acts of insight'. Whether within or across organisations, stage setting implies the creation of generative platforms allowing for ongoing acts of insights (see Garud & Turunen, 2021 for more details). In this regard, Koutroumpis et al. (2021) have argued that digital technologies are 'technologies of invention' that change both the nature of the innovation process and the types of products and services created. In particular, they show that instrument technologies – general-purpose technologies that have spurred invention in many sectors for decades – are increasingly digitalised. These 'digital instruments' are at the heart of 'smart' industrial systems, also known as the Internet of Things (IoT) and Industry 4.0, that drive the innovation process in many economic sectors.

These are just some of the issues impacting theory and practice because of digital technologies and the innovations they are fostering. To explore them further, we review the contributions of the papers in this special issue and integrate them with extant knowledge about the particular characteristics of digital technologies driving innovation. Further drawing from the papers in this special issue, we show how studying the process of digital innovation enables researchers to generate insights that may be relevant to

understand innovation as a process more generally. We conclude with a call for more research into the processes of digital innovation, and the insights such research can bring to our understanding of traditional innovation.

Characteristics of digital innovation

Several characteristics of digital innovation distinguish it from traditional innovation. An important differentiating characteristic is that digital innovation has less predefined innovating agency and blurs innovation outcomes in terms of scope and reach (Nambisan et al., 2017; Yoo et al., 2012). In this special issue, Lyytinen (2021) argues that the difference is more significant than just replacing analogwith digital information in specific contexts and settings, as the new capacities associated with digital innovation enable new assemblages that recombine new and old components in fundamentally different ways. Specifically, he explains that digital innovation advances in a three-pronged process of operational embedding, virtual embedding, and contextual embedding involving software, hardware, and the layered and modular architectures within which they operate (Yoo et al., 2010). More generally, and also in this special issue, Urbinati et al. (2021) argue for the importance of considering digital innovation *as a process*, and as such focus on its phases, underlying mechanisms, barriers, and enabling factors.

In his analysis, Lyytinen (2021) argues that the process of digital innovation is driven by the generativity of digital technologies (for a recent review, see Thomas & Tee, 2021). Gawer (2021) echoes these sentiments by arguing that generativity and the process of platformization are typical characteristics of digital innovation and its outcomes, which at times may be difficult to control (Leiponen et al., 2021). Moreover, Nambisan (2020) shows that the generativity of digital technology has opened up powerful new ways for multinational enterprises to connect with global markets, resources, and partners, and to pursue innovation in foreign markets. At the same time, Hron et al. (2021) caution that the generativity of digital technology may lead to innovation drift. As they explain, the properties of digital technology as being editable, reprogrammable, and distributable may cause digital innovation to gradually shift from radical innovation towards more incremental improvements.

Because of generativity, the evolutionary process surrounding digital technologies is different from the evolutionary process of technologies that came before (Lee & Berente, 2012; Nylén & Holmström, 2015). For instance, digital technologies do not tend to follow the canonical two-stage evolution with the era of ferment and incremental innovation, separated by the emergence of dominant design (Anderson & Tushman, 1990). Instead their evolution is even more dynamic and unpredictable than the already complex development of traditional technologies (cf. Garud et al., 2008). For instance, Leiponen et al. (2021) speculate that the limited governability of blockchain platforms can give rise to an abundance of generativity and unpredictability in these ecosystems. While their argument focuses on the macro-level evolution of digital technology, Malhotra and Majchrzak (2021, p. 1) observe similar complexities on the micro-level as digital innovation is characterised by 'fluid digital innovation structures and processes'. The evolution

of digital technologies can be complicated by the fact that knowledge evolution patterns are not explicitly evident ('hidden'), even though they implicitly impact the innovation process and outcomes (Malhotra & Majchrzak, 2021).

A further characteristic of digital technologies is that they coevolve with a myriad of interdependent technologies. One important aspect of digital technologies is their connectivity and embeddedness across various levels (Yoo et al., 2010). Digital technologies are often embedded in platforms which are themselves embedded in other platforms or ecosystems (Legenvre et al., 2021), which Gawer (2021) considers emblematic of the digital age. Leiponen et al. (2021) illustrate the complex interdependencies, connectivity, and embeddedness of digital innovation through their investigation of the fundamental features of blockchain platform ecosystems. From a different perspective, Lyytinen (2021) shows that the embedding of digital technology not only entails embedding in other technological systems (both digital and physical), but also embedding in social systems. He points out that these different types of embedding are relatively independent of how they occur, and that the conditions that shape advances and goals for each type of embedding are distinct. In doing so, he argues that each digital embedding effort constitutes a specific 'leverage point' for further and expansive digital innovation.

A further distinctive characteristic of digital innovation is that it rarely occurs within single organisations or in settings featuring formal 1–1 supplier relationships. Closely related to the notion of user innovation (Von Hippel, 2005), open innovation (Chesbrough, 2003), and network-centric innovation (Nambisan & Sawhney, 2011), this means that the governance and orchestration of innovation are often decentralised, radically so in the case of blockchain ecosystems (Leiponen et al., 2021). For instance, Autio (2021) suggests an ecosystem orchestration framework that distinguishes between technological, economic, institutional, and behavioural layers of the ecosystem (see also Autio & Thomas, 2018; Garud & Kumaraswamy, 1995). In an empirical study of a Dutch health insurance company, Reus et al. (2020) show how digital technology enabled increasing numbers of bridging members – people who connect otherwise unconnected online groups – to mitigate a decrease in the rate of knowledge expansion.

Digital innovation as a means to study innovation generally

While digital innovation can be distinguished by its characteristics, it also serves as a powerful context with which to study innovation more generally, particularly the meta-characteristics of innovation processes. The reality is that digitalisation cuts across the entire innovation value chain. Consequently, many aspects of digital innovation affect the theory and practice of innovation more generally.

One aspect of digital innovation that lets us better study and understand general innovation processes is the speed with which it unfolds. For instance, the many iterative steps involved in an innovation process occur more rapidly in digital contexts. This phenomenon, which Malhotra and Majchrzak (2021) call the 'fruit fly effect', provides innovation scholars with evidence on many cycles of innovation that previously required years or decades to unfold. Furthermore, the ability to monitor parallel and multiple sequential innovation cycles means that research into digital innovation makes it possible

for scholars to benefit from a fast-paced evolution of knowledge accumulation. Ideally, this implies that studying digital innovation can provide insights on complex processes such as the co-evolution of innovations in ecosystem contexts.

A second aspect of digital innovation is the observability of the innovation process due to the self-documenting nature of digital innovation (Garud et al., 2008). As noted by Malhotra and Majchrzak (2021), the interaction between participants in digital innovation occurs through digital knowledge artefacts. Essentially, this means that when digital innovation occurs, data is created at all stages of the innovation process, leaving digital traces (Garud et al., 2011; Pentland et al., 2020). This characteristic facilitates collaboration in digital innovation: as participants come and go, they can read what others have contributed and then add their contributions. This feature of digital innovation has direct implications for innovation research as the collection of data of innovation processes was difficult for many studies in the pre-digital age. However, with digital innovation, we are able to naturally document much more of the phenomenon. Digital innovation provides a wealth of data not only of the characteristics of the digital innovation outcomes, but also of the processes and micro-level interactions that lead to their creation and dissemination.

A third aspect of studying digital innovation emerges as a product of the first two: the relationships between the multiple levels of analysis (such as the micro, organisational and macro) can be more easily traced due to the speed, scale, and observability of the digital innovation process. This stands in stark contrast to traditional and non-digital settings where it is more challenging to study innovation across multiple levels. In sum, the availability of digital traces of interactions allows the study of the processes of innovation in unprecedented ways.

Because of these advantages in studying digital innovation, using digital innovation as a 'model of' also provides a 'model for' the study of innovation processes more broadly in non-digital, and hybrid contexts. For instance, the investigation of Gonzalez and Gulbrandsen (2021) into the Norwegian newspaper industry illustrates how an established industry with a resilient identity can learn how to use the digital space to adapt and innovate effectively. They find that continuous experimentation and collective deliberation on the fit between innovation and the dominant identity is a key process of innovation adoption more generally. Similarly, Garud and Karunakaran (2018)document how participative experimentation at Google using digital tools led to the emergence of Gmail and AdSense, arguably two of the main digital innovations among many at Google that led to its transformation over time. Relatedly, Leonardi et al. (2021) show how digital simulation models can be leveraged to explain and predict complex systems. As complex tools, however, these models must become integrated into a social context characterised by differences in technical knowledge about when, how, and why the models are useful. They compare three very different contexts and show that building in digital innovations requires appeals to the credibility of the model's analysis, the utility of its outputs, and to negotiate unavoidable political issues that emerge from differing values among parties in the innovation process. These papers show that the abundance of digital trace data allows not only scholars to learn, but also allows practitioners to better understand complex processes, allowing complex technical and socio-technical systems to be simulated (cf. Parmar et al., 2020).

Conclusion

While this introductory essay provides a background for and an overview of this special issue on digital innovation, it also begins sketching out the frontier of our knowledge on the topic. As an emerging phenomenon, digital innovation is likely to have a significant impact on innovation research in general, offering great opportunities for research while creating new challenges as well. While researchers have established some attributes of digital innovation, others have yet to be charted. Researching these attributes can offer greater insight into digital transformation processes and the disruptions involved (Christensen, 1997; Larsen & Bogers, 2014). We present our introductory essay and the articles in the special issue as an invitation for scholars to further investigate digital innovation by leveraging its insights to better understand innovation more generally.

Disclosure statement

No potential conflicts of interest were reported by the authors.

ORCID

Marcel L. A. M. Bogers http://orcid.org/0000-0002-7942-3561
Llewellyn D. W. Thomas http://orcid.org/0000-0002-2090-0490
Philipp Tuertscher http://orcid.org/0000-0001-8906-936X

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