Process Science: The Interdisciplinary Study of Continuous Change

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Abstract

The only constant in our world is change. Why is there not a field of science that explicitly studies continuous change? We propose the establishment of process science, a field that studies processes: coherent series of changes, both man-made and naturally occurring, that unfold over time and occur at various levels. Process science is concerned with understanding and influencing change. It entails discovering and understanding processes as well as designing interventions to shape them into desired directions. Process science is based on four key principles; it (1) puts processes at the center of attention, (2) investigates processes scientifically, (3) embraces perspectives of multiple disciplines, and (4) aims to create impact by actively shaping the unfolding of processes. The ubiquitous availability of digital trace data, combined with advanced data analytics capabilities, offer new and unprecedented opportunities to study processes through multiple data sources, which makes process science very timely.

1. Introduction

We live in an age of process. Many core phenomena of our time speak to complex dynamics involving change: Climate change, globalization, the platformization of economies, as well as societal movements including #meToo, #FridaysForFuture, #blackLivesMatter, or political decisions, have in common that we can learn a lot more about them if we think of them as ongoing processes, rather than stable objects or systems. Take the Covid-19 pandemic: At the heart of the present pandemic is a virus (an object) that is constantly changing: it is continually evolving and mutating, and is tackled through waves of pharmaceutical and non-pharmaceutical interventions. Climate change has been an ongoing yet accelerating progression of events that manifest in singular, increasingly catastrophic events such as flooding, bushfires, and drought. While societal movements often start with catalyst events (think of George Floyd's death), it is the unfolding of collective action which follows in response that generates political pressure and, in some cases, mitigating action. In the

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economy, we have seen the rapid rise of platform businesses, such as Uber, that do not offer new products or services but change the way we produce and consume them.

To study these and other contemporary phenomena, we need to embrace the fact that the only constant in our world is change. Phenomena unfold, evolve and wane, and occur on a macro, meso and micro level. Our world is not made up of things, it is made up of processes that change everything around us. However, a view that sees the world primarily as flowing as opposed to being in a stable state is not trivial. It goes against many of our deeply ingrained assumptions that the world espouses stability and permanence (Chia, 1999). The latter assumption has been at the core of scientific investigation, focusing on objects, their properties and relationships. In contrast, an orientation towards processes—broadly defined as the ordering of change—embraces a view of the world that is evolving and becoming (Tsoukas & Chia, 2002). In a world where nothing is quite settled, two new questions take centerstage. On the one hand, the prime question of scientific understanding must change from "what is?" to "how is it changing?". On the other hand, a new question emerges: as change both occurs naturally and can be constructed artificially, we need to ask: "how can we influence change?".

Process science seeks to foreground the mechanisms and drivers that create, trigger, foster, prevent, accelerate, or slow down processes. Essentially, a focus on process pushes us to understand *how* change unfolds. However, change is not only part of the natural world around us, but also an artificial construct shaped by human action. Therefore, advancing our understanding of phenomena in terms of their underlying processes also provides us with new opportunities for *influencing* change. If we know why, how and when certain changes occur, we can design and study interventions. This is important as many recent claims suggest that scientists should take on the roles of real-world problem solvers (Gaieck, Lawrence, Montchal, Pandori, & Valdez-Ward, 2020). Extending Pettigrew (1997), process science encourages scholars not only to capture processes in flight—it also encourages them to change the direction of the flight.

We conceptualize process science as the interdisciplinary attempt to investigate the nature of evolution, transition, and change on various levels of abstraction. While every field is aware of processual phenomena to some extent, there is no established field that puts processes at its center. The goal of process science is to reconcile methods, theories, and approaches of various scientific fields to establish a comprehensive understanding of processes as well as means to design interventions to processes. Our motivation to introduce process science is further complemented by new means to study processes: the ever-expanding datafication, which affects all areas of our private and professional lives, generates comprehensive data on processes dynamics; and computational techniques from various disciplines (Lazer et al., 2020; Simsek, Vaara, Paruchuri, Nadkarni, & Shaw, 2019) enable the analysis of process dynamics across various levels. Drawing on various claims that the use of digital data yields unprecedented opportunities for research (Lazer et al., 2020), process science aims at integrating data from diverse sources, including company data, environmental data, body data, and many others. Process science provides a platform for disciplines to jointly advance the study of processual dynamics and find ways to change them. Process science is not a thing. We consider it as *process science-ing*: an evolving process itself shaped by anyone who engages with it.

2. Conceptualizing Process Science

Processes have been playing an important role in various research domains (Recker, 2014). These include psychology, linguistics, anthropology, politics, economics, and others (Cornwell, 2015). In the broadest sense, a process brings about change through a sequence of temporally and causally related activities or events. To this end, the term has been appropriated by various disciplines in different ways (Mendling, Berente, Seidel, & Grisold, 2021; Pettigrew, 1997; Van de Ven & Poole, 1995). For example, in the context of sociology, processes serve to uncover the temporal aspects of a given phenomenon, e.g. life trajectories (Abbott, 1995). In contrast, computer science uses the term to depict intended computational sequences to accomplish a specific outcome. In the natural sciences, researchers focus on processes to unravel mechanisms that explain how certain phenomena evolve and lead to distinct outcomes (Cornwell, 2015; Leenders, Contractor, & DeChurch, 2016). Management and business research emphasize the importance of designing processes to enable business operations (Dumas, La Rosa, Mendling, & Reijers, 2018; Hammer & Champy, 1993). As different research communities have applied a process perspective to different phenomena, they developed different methods to study them, and a cross-fertilization among research fields may lead to new methods in order study how and why certain phenomena evolve and change over time (Lazer et al., 2020; Mendling et al., 2021; Simsek et al., 2019). However, scientific discourses on processes continue to be scattered across different fields (Abbott, 1995; Mendling et al., 2021). In light of this, the core of process science is an interdisciplinary field of study, providing a platform to foster continuous exchange across various isolated fields.

The acute relevance of process science is tied to the changes and shifts associated with digital technologies (Mendling, Pentland, & Recker, 2020). Van der Aalst and Damiani (2015) identify four historical logics in the context of operational process research, namely (1) the study of single tasks, (2) a focus on the process as a whole, (3) the use of information technology to integrate and automate, and (4) the study of devices that interconnected through the internet, forming distributed systems such as in smart manufacturing. Through the expanding means provided by digital technologies, we see the emergence of a fifth logic, in which processes become central to understanding the dynamics of socio-technical networks. It is not only that technical infrastructure such as sensor technology, personal digital assistants, and smart environments create dynamics that transcend organizational containers, but phenomena like social-media "shit storms", crowdsourcing, the Bitcoin hype, cyber bullying, the Fridays for Future movement, spreading of fake news, or self-organized disaster relief can hardly be grasped without taking a process view as a starting point (Mendling et al., 2020; Winter, Berente, Howison, & Butler, 2014): More than ever, what we are observing is continuously changing evolving and—at best—stable "for now" (Feldman, Pentland, D'Adderio, & Lazaric, 2016).

The abundance of digital technologies also leads to new opportunities to study processes and their underlying dynamics. Digital traces produced by these technologies offer insights into activities of actors that would not have been possible to study before (Akemu & Abdelnour, 2020), since manually obtaining traces is not feasible at large scales. Digital trace data in private as well as work-related contexts offer new opportunities to study how phenomena evolve in terms of underlying sequences of events (Pentland, Pentland, & Calantone, 2017). This may open up a powerful view to understand and predict how phenomena change and behave over time (Lazer et al., 2020; Oliver et al., 2020; Pentland et al., 2017). Using digital trace data, we can study phenomena at different levels, including the micro-, meso-, and macro-level (e.g., individual and organizational level). This can complement established theories, e.g. in the social sciences (Lazer et al., 2020). Embracing such opportunities and establishing a dialogue across disciplines to study processes from an integrated viewpoint is at the core of process science.

Using the term 'process science', we draw on and extend claims that have been made before. From a computer science perspective, van der Aalst and Damiani (2015) have used the term to denote "the broader discipline that combines knowledge from information technology and knowledge from management sciences to improve and run operational processes." (p. 2). By this account, process science extends data science which is "an inter-disciplinary field that uses scientific methods, processes, algorithms and systems to extract knowledge and insights from many structural and unstructured data". Furthermore, Mendling (2016) used the term in the context of business process management to call for more scientific and empirical research in the field. The term process science has also been used as a specific field of engineering that is concerned with fluids and circulation (Judd & Stephenson, 2002; Velis, Longhurst, Drew, Smith, & Pollard, 2009). While these works approach process science from within the frame of a specific discipline, they share (for example) an interventional perspective. In turn, we intend to emphasize process science in terms of an interdisciplinary study of processes. Process thinking is put center stage and its use should not be limited to a specific research discipline.

We define process science as follows:

Process science is the interdisciplinary study of continuous change. By process, we mean a coherent series of changes that unfold over time and occur at multiple levels.

3. Key Tenets of Process Science

Process science emphasizes the following key charactersistics; (1) process are in the focus, (2) we scientifically investigate processes (3) through an interdisciplinary lens, and (4) we intend to influence and change processes to create impact. We will explain these tenets in the following. Fig. 1 depicts a core summary of process science.

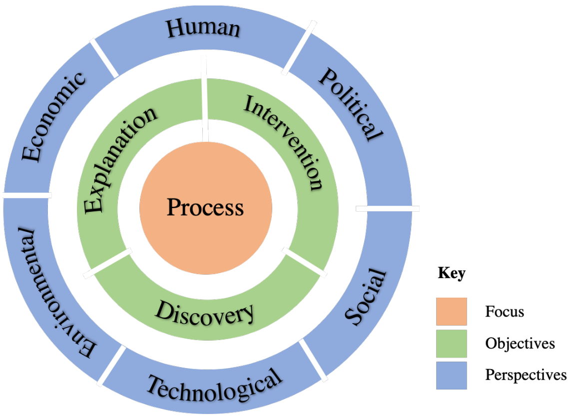

Fig. 1: Process Science Framework

At the core of process science is the study of processes (focus). It aims to describe, explain and intervene in processes (objective). Thereby, it embraces an interdisciplinary viewpoint, integrating contributions from various disciplines (perspective); some of these disciplines are exemplified here.

3.1 Processes are in the focus

Process science offers an opportunity to reconsider one of our basic assumptions: is the world made of objects or processes? Across a wide range of disciplines, we have been trained to think of object first. For example, computer science and information systems adopt the stance that processes change the properties of objects that exist *a priori* (Wand & Weber, 1993). Influential process modeling languages such as UML and BPMN share this commitment to representing "objects first" (Chinosi & Trombetta, 2012; Fowler, 2004). Other disciplines, such as biology, are beginning to question the object-first perspective and consider a "process first" perspective. Nicholson and Dupré (2018, p. 3) propose that "the living world is a hierarchy of processes, stabilized and actively maintained at different timescales." They argue that the entities we recognize as objects (e.g., cells or organisms) are the result of those processes. In organization studies, the "process first" perspective has also been proposed (Langley & Tsoukas, 2017; Tsoukas & Chia, 2002).

In practice, processes and objects always co-exist: the fire burns the wood and the wood fuels the fire. However, the shift in perspective from object-first to process-first affords a novel way to think about familiar problems. For example, rather than focusing on chickens and eggs, we could focus on the on-going biochemical and evolutionary processes that bring them *both* into existence. For our purposes, the process-first perspective may provide a useful way to see analogies across domains that have different objects but similar processes.

The core of process science is to think about the world in terms of processes. Table 1 exemplifies that process science is concerned with a variety of processes, such as political, mental, mathematical or biological processes (Rescher, 2000). We distinguish between different forms of processes according to (1) broader criteria and (2) specific types of processes, which all fall under the proposed definition of process science. We also provide (3) specific examples for each type of process. Within process science, we take different perspectives to study these processes, which can be informed by e.g. social sciences, such as organizational sciences, or technical research, such as computer science.

Criterion	**Distinction of process**	
	Types of Process	***Example***
Structure of process	Causal processes (one event or process contributes to the production of another event or process)	Seed germination
	Thought-sequencing process (do this, then that)	Solving an equation
	Ceremonial process	Baptism
	Performatory process	Playing poker
Form of process	Biological processes	Mitosis
	Mental processes	Perceiving
	Political processes	Voting
	Mathematical processes	Differential equation
Outcome of process	Productive process	Manufacturing process
	Problem-solving process	Solving a criminal case
	Social-stylization processes	Performing a wedding
Origin of process	Owned process (follows from thing or subject, intentional)	Musician performs a piece of musik
	Unowned process (non-intentional, do not come from subject or thing)	Thunderstorm

Tab. 1: Distinctions of process relevant for process science (drawing on and extending Rescher, 2000)

It is important to note that process science includes both "owned" and "unowned" processes (Rescher, 2000). Processes are owned when they involve agency and intention. Unowned processes occur without the intentions of any agent. In very few cases, there will be a clear-cut distinction between owned and non-owned processes. When looking at real-world phenomena, owned and unowned processes influence one another. Owned processes, such as production processes, influence unowned processes, such as environmental developments. Vice versa, unowned processes have an impact on owned processes, as it has been shown dramatically by the Covid-19 pandemic. As process scientists, we aim to study both forms of processes and how they interplay. We consider the interplay of processes as a continuum where processes within a phenomenon are owned and unowned to different degrees (see Fig. 1). For example, when studying the evolvement of the Covid-19 pandemic, we are considering unowned process, such as the emergence of the virus, as well as owned processes, such as measures to keep it under control (Oliver et al., 2020). Owned and unowned processes may exhibit influences to different degrees at different points in time.

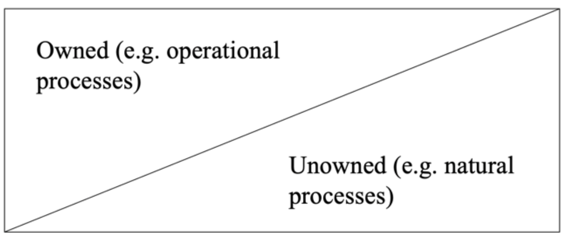

Fig. 1: Taking an integrated view on different forms of process in process science

3.2 A Science of Discovering, Explaining and Intervening into Processes

Process science welcomes all approaches to generating new scientific knowledge through deduction, induction, and abduction. Its key idea is that a focus on process advances our understanding of various phenomena because it directs our attention to underlying causal-temporal relations constituting a specific phenomenon. When we know why and how a specific process unfolds, we are better prepared to re-direct and change it. Process science subsumes three broad activities, which are depicted in Table 2.

Discovery emphasizes the detection of (emergent) dynamics constituting the phenomenon of interest. It can be challenging to detect emerging and evolving processual dynamics and their significance may be understood retrospectively (Chia, 1999). The discovery activity capitalizes on the potentials of digital trace data to explore all sorts of phenomena (Lazer et al., 2020).

Explanation aims at understanding the dynamics of processes. It explains how and why processes unfold. Explanation activities seek to identify cause-effect relations (Markus & Rowe, 2018), specifically in relation to their situatedness, e.g., in temporal and spatial contexts. Access to a wide range of data sources will be beneficial, and again, the vast potentials associated with digital trace data may come into play (Lazer et al., 2009). Furthermore, an in-depth understanding of a process enables predictions about the possible future states of the process. Thereby, one can anticipate patterns arising in the sequence of activities and events in a specific context, or the evolvement of a process in relation to certain indicators and factors, such as performance indicators in business environments (Poll, Polyvyanyy, Rosemann, Röglinger, & Rupprecht, 2018; Vergidis, Tiwari, Majeed, & Roy, 2007). In terms of methodological approaches, it is important to establish a comprehensive understanding of a process, for example, by collecting and integrating contextual information through complementary data sources, such as observations.

Intervention aims at changing processes as they unfold. This resonates with recent claims across various fields that science should contribute more strongly to solving real-world problems (Gaieck et al., 2020; Oliver et al., 2020; Rose, 2018). Such interventions build on the cause-effect relations identified before, and can include one or many measures to interfere with how the process seems likely to unfold in the future. For instance, design-oriented research can generate prescriptions on how to organize a specific process, utilize a specific technology or communicate process change to people in order to meet specific objectives (Hevner, March, Park, & Ram, 2004; Van Aken, 2005). Interventions are based on an envisioned goal, e.g., to prevent a process from causing damage. It aims for utility and develops knowledge on how to solve problems related to process interventions, presented e.g., by methods, models or principles. Borrowing established methodological approaches—such as design science research in the information systems field—can provide frameworks to plan and evaluate intervention activities.

While these three activities are core to process science, not all of them have to be necessarily involved in a process science project. Depending on the phenomenon, and the questions being pursued, a study needs to make explicit its core focus: discovery, explanation or intervention.

Phase	Process Science Activities	
	Goals	***Exemplary Methods***
Discovery	Capturing and describing processes	Techniques, such as process mining, to create descriptive representations of processes using digital event data; event-based architectures to organize data collection and storage as well as computational methods to analyze the data and to identify patterns in processes.
Explanation	Understanding why, how and when a process unfolds	Methods supporting sense-making around processes in a specific context, e.g. qualitative empirical research to study the context in which a pattern is situated. Leads to propositions or entire theories on cause effect relations embedded in a situational context.
Intervention	Intervening and shaping the process into desired direction	Methods to develop and evaluate interventions to processes. Applying e.g. design-oriented research, developing interventions based on explanatory research and evaluating effects of such interventions in process event data.

Tab. 2: Process science activities

Process science progresses by systematically making use of various and novel data sources. What is important, however, is that these data reveal temporal information to infer when they took place. We refer to these data as "event data" as they reflect the occurrence of something that happened at some point in time (van der Aalst, 2016). Such data can come from traditional qualitative research designs or from digital trace data, such as time-stamped production data, sensor data, or social media data (Lazer et al., 2020). To understand the interplay of processes, it is important to use data collected across different levels of abstraction (Langley & Tsoukas, 2017; Rescher, 2000).

3.3 An Interdisciplinary Science

Process science is interdisciplinary. It is open to all disciplines that can make contributions to describe, understand and intervene in processes. We do not suggest re-labeling existing fields or changing their agendas, but rather, we envision that process science integrates their contributions, their methods and theories to study processes. It is only through looking beyond single disciplines, and integrating such disciplinary views and findings, that processes will be understood more comprehensively. Similar arguments have been made before. For example, Abbott (1995) suggests that research in sociology can benefit from importing technical models from operational research to think about social processes. In a similar vein, claims in the business process management field assert that scholars should embrace openness, pluralism, and integration of other processual views to advance established views on process work (Kerpedzhiev, König, Röglinger, & Rosemann, 2020).

Process science seeks to function as an interface between disciplines, synthesizing assumptions and methods to promote a holistic study of processes. If we are interested, for instance, in lowering the environmental load of our economic and social behavior, it makes sense to not limit the view on organizations or the environment but to study processes within the economy and society to capture all relevant effects, e.g. by synthesizing perspectives from business, economy and environmental studies (Hertz, Garcia, & Schlüter, 2020; Song, Sun, & Jin, 2017). Table 3 shows how process science integrates a wide range of disciplines.

Perspective	Contributing to Process Science	
	Focus	***Exemplary Discipline***
Human	Cognitive and affective states of people and their change over time.	▪ Psychology ▪ Neuroscience ▪ Anthropology
Social	Social interactions and how they change over time	▪ Social Science ▪ Organization Science ▪ Information Systems Research
Environmental	Changes in man-made and non-owned constructed or occurring systems	▪ Natural Science ▪ Urban Science ▪ Architecture
Political	The governance of social behaviors and change	▪ Political Science ▪ Law ▪ Ethics
Economic	Economic factors influencing processes, including mechanisms of value creation, in particular, the production, distribution, and consumption of goods and services	▪ Management Science ▪ Decision Science ▪ Organization Science ▪ Economics
Technological	Applications and algorithms involved in the enactment, capture, or analysis of change	▪ Computer Sciences ▪ Engineering ▪ Data Science

Tab. 3: Exemplary disciplines contributing to process science from different perspectives

One contemporary field of research that exemplifies the key ambitions of process science is process mining. Process mining has been developed to analyze and visualize business process work by processing event log data that occur when people interact with information technology (van der Aalst et al., 2011). Over the past years, process mining has received considerable attention in research and practice, leading to a rich repertoire of techniques and algorithms (e.g. Augusto et al., 2018; van der Aalst, 2016). While process mining research has been originally tied to the field of computer science, the technology has attracted increasing interest from other fields, such as management and organizational research (Davenport & Spanyi, 2019). In addition to this, recent claims stress that the functionalities of process mining can also be used for other purposes, such as research. Accordingly, it offers new opportunities for theorizing in empirical research; for example, the technology can be used to find patterns in organizational change processes (Grisold, Wurm, Mendling, & vom Brocke, 2020; Pentland, Vaast, & Ryan Wolf, 2021) or explore working practices (Malinova, Gross, & Mendling, 2019). Taken together, process mining provides a good example for what we envision to be at the core of process science: a field of research that is strongly concerned with analyzing processual phenomena blending the interests of various research domains and exploiting the potentials associated with digital trace data.

It should be noted that it may pose challenges for different disciplines contributing to process science. This is because they draw on different assumptions, theories and methods. For instance, organizational scientists draw on management science when studying processes (Sydow & Schreyögg, 2013), but these exclude perspectives on cognitive processes from their analysis, as embraced, for example, by neuroscience and psychology. Nonetheless, we believe that accumulating knowledge from many disciplines will be highly beneficial, as long as such views are made transparent, and, thus, can be considered when interpreting and discussing results and designing interventions.

3.4 A Science of Impact

Process science strives to make an impact. Process science is inherently pragmatic as it strives to create knowledge that has instrumental value in solving real-word problems (Dewey, 1946). As such, process science aims to produce knowledge that can make an impact on people, organizations and society. In light of the manifold and severe grand challenges we are facing today (George, Howard-Grenville, Joshi, & Tihanyi, 2016), process science should enable the development of effective solutions, such as new ways to organize processes as well as new ways to intervene in processes.

The United Nations General Assembly, for instance, has collected 17 interlinked goals designed to be a "blueprint to achieve a better and more sustainable future for all", which are referred to as the "Sustainable Development Goals" or simply the "Global Goals". These goals include, among others, the end of poverty, good health and well-being, quality education, gender equality, affordable and clean energy, decent work and economic growth, as well as peace, justice and strong institutions, to name but a few. All of these goals are influenced by processes at various levels, and accomplishing any one of these goals is going to be a process itself. For instance, the goal "good health and well-being" is dependent on dynamics that cover both non-owned processes, as illustrated (for example) by the spread of the pandemic, as well as owned processes, e.g. measures we take to improve the health and well-being of people. True to its mission, process science can investigate and design ways to influence the evolution of these processes for the better.

As we have argued before, contributions are enabled also by a rich and detailed understanding of how and why processes unfold over time. Process science embraces processes on various levels and in different contexts, including both naturally evolving and intentionally designed processes, and examines how they interact over time. Insights we gain here shall enable and guide interventions to affect the course of things over time. Process science is not only about capturing reality in flight—it is also about *influencing* it while it unfolds (Pettigrew, 1997).

4. Conclusion

This paper introduces and conceptualizes a new scientific field: process science. Process science is concerned with the understanding of processes of different kinds aiming to inform interventions to and the design of processes. We have established theoretical foundations for process science, and provided reasons why this endeavor is very timely. The next important step is to start process science-*ing*: bringing process science to life and starting research projects that embrace and advance the field. Process science is in the making. Everyone who wants to engage with it is welcome to shape the field as it evolves.

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References

Abbott, A. (1995). Sequence analysis: new methods for old ideas. *Annual review of sociology, 21*(1), 93-113.

Akemu, O., & Abdelnour, S. (2020). Confronting the digital: Doing ethnography in modern organizational settings. *Organizational research methods, 23*(2), 296-321.

Augusto, A., Conforti, R., Dumas, M., La Rosa, M., Maggi, F. M., Marrella, A., . . . Soo, A. (2018). Automated discovery of process models from event logs: Review and benchmark. *IEEE Transactions on Knowledge and Data Engineering, 31*(4), 686-705.

Chia, R. (1999). A 'rhizomic'model of organizational change and transformation: Perspective from a metaphysics of change. *British journal of management, 10*(3), 209-227.

Chinosi, M., & Trombetta, A. (2012). BPMN: An introduction to the standard. *Computer Standards & Interfaces, 34*(1), 124-134.

Cornwell, B. (2015). *Social Sequence Analysis - Methods and Applications*. New York, NY: Cambridge University Press.

Davenport, T. H., & Spanyi, A. (2019). What process mining is, and why companies should do it. *Harvard Business Review*.

Dewey, J. (1946). *The public and its problems. An Essay in Political Inquiry*. Chicago, US: Gateway Books.

Dumas, M., La Rosa, M., Mendling, J., & Reijers, H. A. (2018). *Fundamentals of business process management* (Second Edition ed.): Springer.

Feldman, M. S., Pentland, B., D'Adderio, L., & Lazaric, N. (2016). Beyond routines as things: Introduction to the special issue on routine dynamics. *Organization Science, 27*(3), 505-513.

Fowler, M. (2004). *UML distilled: a brief guide to the standard object modeling language*: Addison-Wesley Professional.

Gaieck, W., Lawrence, J., Montchal, M., Pandori, W., & Valdez-Ward, E. (2020). Opinion: Science policy for scientists: A simple task for great effect. *Proceedings of the National Academy of Sciences, 117*(35), 20977-20981.

George, G., Howard-Grenville, J., Joshi, A., & Tihanyi, L. (2016). Understanding and tackling societal grand challenges through management research. *Academy of Management Journal, 59*(6), 1880-1895.

Grisold, T., Wurm, B., Mendling, J., & vom Brocke, J. (2020). *Using Process Mining to Support Theorizing About Change in Organizations.* Paper presented at the Proceedings of the 53rd Hawaii International Conference on System Sciences, Maui, US.

Hammer, M., & Champy, J. (1993). *Reengineering the Corporation*. New York, NY: Harper.

Hertz, T., Garcia, M. M., & Schlüter, M. (2020). From nouns to verbs: How process ontologies enhance our understanding of social-ecological systems understood as complex adaptive systems. *People and Nature, 2*(2), 328-338.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, 75-105.

Judd, S., & Stephenson, T. (2002). *Process science and engineering for water and wastewater treatment*: IWA publishing.

Kerpedzhiev, G. D., König, U. M., Röglinger, M., & Rosemann, M. (2020). An exploration into future business process management capabilities in view of digitalization. *Business & Information Systems Engineering*, 1-14.

Langley, A., & Tsoukas, H. (2017). *The SAGE handbook of process organization studies*: Sage.

Lazer, D., Pentland, A., Adamic, L., Aral, S., Barabási, A.-L., Brewer, D., . . . Gutmann, M. (2009). Computational social science. *Science, 323*(5915), 721-723.

Lazer, D., Pentland, A., Watts, D. J., Aral, S., Athey, S., Contractor, N., . . . Margetts, H. (2020). Computational social science: Obstacles and opportunities. *Science, 369*(6507), 1060-1062.

Leenders, R. T. A., Contractor, N. S., & DeChurch, L. A. (2016). Once upon a time: Understanding team processes as relational event networks. *Organizational Psychology Review, 6*(1), 92-115.

Malinova, M., Gross, S., & Mendling, J. (2019, Dec. 15-18). *Researching Information Systems Methods using Method Mining-A Case Study on Process Improvement Methods.* Paper presented at the

Fortieth International Conference on Information Systems (ICIS), Munich, Germany.
Markus, M. L., & Rowe, F. (2018). Is IT changing the world? Conceptions of causality for information systems theorizing. *MIS Quarterly, 42*(4), 1255-1280.
Mendling, J. (2016). *From Scientific Process Management to Process Science: Towards an Empirical Research Agenda for Business Process Management.* Paper presented at the ZEUS.
Mendling, J., Berente, N., Seidel, S., & Grisold, T. (2021). Pluralism and Pragmatism in the Information Systems Field: The Case of Research on Business Processes and Organizational Routines. *The Data Base for Advances in Information Systems, 52*(2), 127–140.
Mendling, J., Pentland, B., & Recker, J. (2020). Building a Complementary Agenda for Business Process Management and Digital Innovation. *European journal of information systems, 29*(3), 208-219.
Nicholson, D. J., & Dupré, J. (2018). *Everything flows: towards a processual philosophy of biology*: Oxford University Press.
Oliver, N., Lepri, B., Sterly, H., Lambiotte, R., Deletaille, S., De Nadai, M., . . . Cattuto, C. (2020). Mobile phone data for informing public health actions across the COVID-19 pandemic life cycle. In: American Association for the Advancement of Science.
Pentland, B., Pentland, A. P., & Calantone, R. J. (2017). Bracketing off the actors: Towards an action-centric research agenda. *Information and Organization, 27*(3), 137-143.
Pentland, B., Vaast, E., & Ryan Wolf, J. (2021). Theorizing process dynamics with directed graphs: A diachronic analysis of digital trace data. *MIS Quarterly, 45*(2), 967-984.
Pettigrew, A. M. (1997). What is a Processual Analysis? *Scandinavian Management Journal, 13*(4), 337-348.
Poll, R., Polyvyanyy, A., Rosemann, M., Röglinger, M., & Rupprecht, L. (2018). *Process forecasting: Towards proactive business process management.* Paper presented at the International Conference on Business Process Management.
Recker, J. (2014). Suggestions for the next wave of BPM research: strengthening the theoretical core and exploring the protective belt. *Journal of Information Technology Theory and Application, 15*(2), 5-20.
Rescher, N. (2000). *Process philosophy: A survey of basic issues*: University of Pittsburgh Pre.
Rose, J. (2018). Help to shape policy with your science. *Nature, 560*, 671-673.
Simsek, Z., Vaara, E., Paruchuri, S., Nadkarni, S., & Shaw, J. D. (2019). New ways of seeing big data. *Academy of Management Journal, 62*(4), 971-978.
Song, J., Sun, Y., & Jin, L. (2017). PESTEL analysis of the development of the waste-to-energy incineration industry in China. *Renewable and Sustainable Energy Reviews, 80*, 276-289.
Sydow, J., & Schreyögg, G. (2013). *Self-reinforcing processes in and among organizations*. Basingstoke, UK: Palgrave Macmillan.
Tsoukas, H., & Chia, R. (2002). On organizational becoming: Rethinking organizational change. *Organization Science, 13*(5), 567-582.
Van Aken, J. E. (2005). Management research as a design science: Articulating the research products of mode 2 knowledge production in management. *British journal of management, 16*(1), 19-36.
Van de Ven, A. H., & Poole, M. S. (1995). Explaining development and change in organizations. *Academy of Management Review, 20*(3), 510-540.
van der Aalst, W. M. (2016). *Process Mining - Data Science in Action*. Heidelberg: Springer.
van der Aalst, W. M., Adriansyah, A., De Medeiros, A. K. A., Arcieri, F., Baier, T., Blickle, T., . . . Buijs, J. (2011). *Process mining manifesto.* Paper presented at the International Conference on Business Process Management.
Van der Aalst, W. M., & Damiani, E. (2015). Processes meet big data: Connecting data science with process science. *IEEE Transactions on Services Computing, 8*(6), 810-819.
Velis, C., Longhurst, P. J., Drew, G. H., Smith, R., & Pollard, S. J. (2009). Biodrying for mechanical–biological treatment of wastes: A review of process science and engineering. *Bioresource technology, 100*(11), 2747-2761.
Vergidis, K., Tiwari, A., Majeed, B., & Roy, R. (2007). Optimisation of business process designs: An algorithmic approach with multiple objectives. *International Journal of Production Economics, 109*(1-2), 105-121.
Wand, Y., & Weber, R. (1993). On the ontological expressiveness of information systems analysis and design grammars. *Information Systems Journal, 3*(4), 217-237.
Winter, S., Berente, N., Howison, J., & Butler, B. (2014). Beyond the organizational 'container': Conceptualizing 21st century sociotechnical work. *Information and Organization, 24*(4), 250-269.