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Digital Disruption and Transformation

Case Studies, Approaches, and Tools

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Preface

Today's global, digital economy requires a holistic view on digitalization and has become central for all non-profit and for-profit institutions. In this special issue, we address key digitalization challenges from company, institutional, industry, and societal perspectives and how these can create our common innovation future.

This special volume presents current academic research and practical findings, covering the field of digitalization. Included contributions are (1) The Evolution of Digital Transformation; (2) Skills and Knowledges expected in Digital Transformation's era; (3) Digital Transformation of Business Model: The Case of Israeli HealthTech; (4) Digital business models and financial performance: On the importance of business renewal; (5) Digital Innovations and transformation in the Public Sector of Panama; (6) Platform-Based Interorganizational Learning for Business Model Innovation: Case Study AgilHybrid; (7) Data-Driven Foresight in Life Cycle Management: An interview study; (8) Digital disruption – how medical doctors employ influencer marketing strategies; (9) The transformation of the accounting profession within a digitalized economy and the impact on accounting education; and (10) SMEs' Innovation Leveraged by Digital Transformation During Covid-19.

We hope that the Special Issue stimulates an intensive discussion between scientists, lecturers, and students from the fields of digitalization and disruption, and that the content will be used in research and teaching. We wish practitioners from the areas of management, strategic planning, and business development to be able to apply the insights to successfully practice digitalization and thus take advantage of the digital potential within their business model and industry.

The editors would like to thank the Springer team and everyone who was involved in the typesetting and design. In particular, we like to thank Mr. Prashanth Mahagaonkar from Springer, and our research assistant at the University of Applied Sciences Neu-Ulm, Verena Mattes, for their valuable input and for their willingness to be at our side with advice and action at any time.

On behalf of all authors, we wish the readers of the compilation a great deal of knowledge and success in their work on digitalization.

Neu-Ulm, Germany
Frederiksberg, Denmark
Aalborg, Denmark
Aalborg, Denmark
Augsburg, Germany
October 2023

Prof. Dr. Daniel Schallmo
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The Evolution of Digital Transformation



Cheng Gong , Xavier Parisot, and Detlef Reis

Abstract The evolution of digital transformation (DT) poses a significant challenge for organizations worldwide, representing both disruptive difficulties and tremendous opportunities for renewing value offerings, business models, and organizational practices. To use DT as an impetus for positive change, however, it is critical that scholars and practitioners have a clear, unified understanding of the concept. We structure our discussion as follows: Sect. 1 of this chapter discusses the confusion around the concept “digital transformation” and its related concepts (i.e., digitization, digitalization). Section 2 presents the etymology of these three concepts’, leading to a discussion of the main etymological reasons behind the confusion. In the Sect. 3, we explore the historical use of these concepts in the pertinent literature; we reveal how scholars have interpreted the concepts inconsistently and associated them with a myriad of different realities/phenomena. Section 4 introduces a concept formation and assessment methodology to lay the theoretical foundation of how concepts can be analyzed and assessed. Section 5 offers a collection of existing definitions of digitization, digitalization, and digital transformation that we selected to analyze their defining attributes. We present a detailed example of how we systematically analyzed and assessed digitization’s historical defining attributes. We then report the results of the same analysis for digitalization and digital transformation to assuage the “fuzziness” issue associated with these concepts. Section 6 sums up and discusses our findings that we hope will inspire academics and practitioners to use these terms carefully and consistently.

Keywords Digital transformation · Digitalization · Digitization · Concept evolution · Reconceptualization

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1 Introduction

World Economic Forum (2017) acknowledged digital transformation as one of the world's most pressing challenges for most organizations. Digital transformation (DT) is challenging how organizations can better meet evolving customer expectations, deliver their value propositions, and respond to a changing living and working environment. The growing penetration of digital technologies in the market inevitably drives organizations to rethink their value chain and draw up a roadmap to successfully embark on the "going digital"-journey. While there is general agreement on its growing importance to an organization's success, the inconsistent use of the term "digital transformation" in academia and business practice generates confusion.

On the academic front, the definitional inconsistency of digital transformation and its related terms (e.g., digitization, digitalization) and the theoretical inconsistency of its implications at multiple levels of analysis hamper the betterment of research. The co-existence of numerous conflicting definitions has rendered these terms meaningless. It creates difficulties in developing a consistent stream of research that builds on what has been done before, thus making it more complicated to define and test relationships for digital transformation theory building (Gong and Ribiere 2021). The vagueness in the literature demonstrates a lack of a comprehensive, unified understanding of digital transformation (Goerzig and Bauernhansl 2018; Haffke et al. 2016; Matt et al. 2015; Morakanyane et al. 2017; Van Veldhoven and Vanthienen 2019). This lack of a homogeneous interpretation of the concept is detrimental to research synergy, leading to wildly contradictory and incompatible research findings unfit to guide business practice.

On the practical front, digital transformation appears to be one of the top priorities on business leaders' agendas (Sundblad 2020). However, a McKinsey (2018) study found that the success rate for implementing DT in organizations is less than 30%; moreover, among those organizations reporting a successful implementation, only 23% improved their organizational performance, and in only 7% of cases were these improvements deemed sustainable. The success rates do not exceed 26% in digitally savvy industries (e.g., high tech, media, and telecom) and fall between 4 and 11% in more traditional industries (e.g., oil and gas, automotive, infrastructure, and pharmaceuticals; De la Boutetière et al. 2018). IBM claims that successful digital transformation took around four years and observed that 85% of efforts fail (Gibson 2018). Moreover, Gartner (2019) predicted that through 2021, digital transformation initiatives would take large traditional organizations, on average, twice as long and cost twice as much as initially anticipated.

Leaders and executives using the term DT inconsistently to describe various strategizing and organizing activities (Warner and Wäger 2019) may risk blurring the distinct direction of organizational strategic moves (e.g., aiming for incremental vs. radical changes). Having an unclear DT vision challenges C-suite managers in claiming authority and clearly defining job responsibility for digital-related projects at the organizational level. Having diverse interpretations of DT makes it harder

to benchmark one's performance against other organizations and industries on DT metrics and best practices at the industrial level.

2 Concepts' Etymology

Exploring the etymology of a term is crucial in concept formation since it reveals all the historical connotations contained in a particular term and opens up "a whole new understanding of the true reality" (Eriksson 2010, p. 5). Indeed, the origin, derivation, and historical evolution of a term explain the multivalence of its meanings, i.e., the multiplicity of its definitions (Gerring 1999). This definitional plurality generates a halo of meanings that can affect how common people, managers, and scholars understand a concept "at first sight." Therefore, a comparison between the existing meanings and the one retained for the conceptual definition is informative in concept formation studies (Eriksson 2010). It helps discriminate between the terms' historical meanings, the actual meanings shared in common languages, and the meaning chosen by scholars. Moreover, the diversity of accepted meanings in the common language helps understand the size and scope of the term's "halo effect" (Dumez 2011) chosen to denominate the concept. The meaning of the term(s) chosen in the seminal definition(s) also determines what kinds of empirical cases the concept applies to, how far this application should go, and where it should stop. In other words, the concept's meaning determines its empirical domain of validity.

The words digital and digitize share a common Latin root: "digit." This term emerged in ancient Latin (1st Century BC) *digitus* originally means "finger or toes," and evolved into modern Latin (since about 1500) *digitalis* means "fingers." The modern use of the term "digital" as an adjective, meaning "of signals, information, or data: represented by series of discrete values (commonly the numbers 0 and 1), typically for electronic storage or processing" started from 1940 (OED 2010). George Stibitz first used the term in 1942 in the expression "digital computer" as a counterpart to the analog (Aspray 2000). "Digital" also means "of a computer or calculator: that operates on data in digital form; (of a storage medium) that stores digital data" (since 1945); "of technologies, media, etc.: involving digital data; making use of digital computers or devices" (since 1948; OED 2010). These historical meanings of the word "digital" laid the foundation of the modern use of the verb "digitize," referring to "converting into a sequence of digits in computer programming, moving from analog number to electronic digits" (since 1953; "Online Etymology Dictionary" n.d).

Etymologically, the word "digitization" is clearly rooted in the verb "digitize," while the word "digitalization" comes from the same Latin root "digital," which serves as one component of the concept "digital transformation." This etymological word commonality inevitably generates confusion between the meanings of these terms, which leads to an interchangeable use of the different terms in both academia and practice. All the concepts discussed above are using common language terms for their concept formation. The multivalent meanings of these terms also blur the

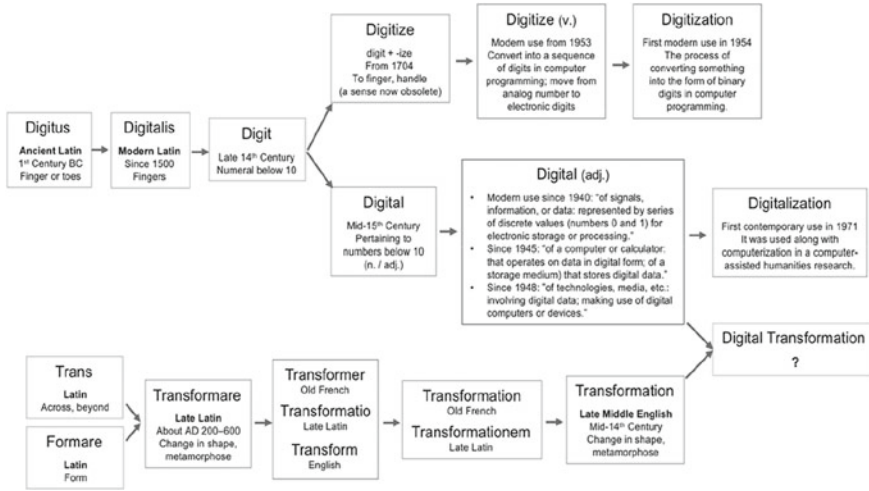


Fig. 1 Etymology of digitization, digitalization, and digital transformation (*Source* Own illustration)

specificities of each concept. Therefore, discrimination between digitization, digitalization, and digital transformation is more challenging to achieve from a common language perspective. While this common denomination strategy improves these terms' familiarity, it decreases the ability to discriminate the concepts. The following exploration of the intension and extension of each of these concepts could solve that matter.

We present a summary of the etymology of the terms digitization, digitalization, and digital transformation (see Fig. 1). A more detailed etymological analysis of these terms can be found in section Appendix 1.

3 The Historical Use of the Concepts

Understanding the history of a concept's formation is critical to recognize the evolution of its scope and limits of application. This history starts with the seminal definition(s) of the concept and continues with the evolution of that definition when confronted with multiple empirical realities. As for digitalization and digital transformation, this historical analysis is critical to explaining the sources of confusion that resulted in the shared common etymological roots. It reveals the definitional overlap and distinctions between these three terms and allows to retrace the chronological emergence of their associated core attributes and auxiliary hypothesis (Lakatos 1978).

3.1 Digitization

The Oxford English Dictionary (OED) traces the first modern use of the term “digitization” jointly with computers to the mid-1950s (OED 2014). According to the OED, digitization refers to “the action or process of digitizing; the conversion of analog data (especially in later use images, video, and text) into digital form.” Some scholars refer it to the technical process of converting analog data into a digital format: an array of zeros and ones stored in a way that makes them readable by computers. With the technological development, the creation, storage, communication, and consumption of information and non-digital products are all being gradually digitized (Press 2015). The development of digital technologies and their implications in different fields have compelled scholars and practitioners to explore digital technologies’ potential, extending from the technical process to their impact on different entities (i.e., organizations, businesses, industries, societies).

A Google Trend search by Seibt et al. (2019) indicates that the term digitization used to be more popular in English-speaking countries, while the term digitalization has been more frequently searched for in continental Europe. No distinction is widely represented in dictionaries, such as the Oxford dictionary, which offers the same definition for both terms. The Encyclopedia Britannica (“Encyclopedia Britannica” n.d.) and sociological dictionaries (Bruce and Yearley 2006; Scott and Marshall 2009; Swedberg and Agevall 2016; Turner 2006) do not define the terms digitization and digitalization. However, both terms are applied in business contexts, public debates by media (Seibt et al. 2019) with correlated meanings that have been causing a great deal of confusion.

In the academic literature, no single seminal scientific definition that all the authors agree upon can be found for each of these concepts. Moreover, all the definitions of digitization are rooted in common language, not in systematic scientific conceptualization. Digitization and digitalization terms are often applied to signify the same objects/phenomenon. The same overlap exists between the use of the term digitization and the term digital transformation. Some authors use different terms interchangeably consciously or unconsciously; others may differentiate one concept while using the other two terms as equivalents implicitly or explicitly. Such confusion or lack of a common conceptual basis makes it impossible to ensure cumulative and sustainable knowledge creation (Sparrowe and Mayer 2011). Consequently, this lack of clarity leads some authors to distinguish these three terms and their associated definitions in their articles to attach one specific term to one specific object/phenomena (e.g., Mergel et al. 2019; Verhoef et al. 2019).

3.2 Digitalization

The first contemporary use of the term “digitalization” along with computerization appeared in Wachal’s (1971) essay that discusses the social implications of

the digitalization of society in computer-assisted humanities research (Brennen and Kreiss 2016). In general, digitalization refers to “the use of digital technologies” (Srai and Lorentz 2019, p. 79). It “loses its more technical aspects to digitization while maintaining the vague ideas of restructuring social life or business, and all the normative connotations they entail” (Seibt et al. 2019, p. 10). Dijk van Jan (2006) noted that digitalization “allows a considerable increase in the production, dispersion, and consumption of information and the signals of communication” (p. 193), and “produces a culture of speed because creative production is assisted by the power of accelerated processing and distribution in computers and networks” (p. 209).

Digitalization is often used as a synonym of digital transformation when describing changes brought by the adoption of digital technologies in society and organizations. Besides, Seibt et al. (2019) argued that the discussion around the digitalization of industry is a debate that got labeled “Industries 4.0,” which is the most prominent field of the industrial application of digitization, digitalization, and automation (Schumacher et al. 2016). Bloomberg (2018) noted that “automation is a major part of the digitalization story, whether it be shifting work roles or transforming business processes generally” (p. 4).

The implementation of IT tools/software in organizations, such as MRP (Material Requirements Planning), Manufacturing Resource Planning (MRP II), ERP (Enterprise Resource Planning), and BPR (Business Process Reengineering), leads to the first generation of digitalization processes. During the 1970s and 1980s, with computer hardware and software development, MRP and MRP II emerged, driven by the need for stronger integration between the functional enterprise silos, the suppliers, and the customers. From the 1990s, ERP (i.e., the adoption of standard software packages) and BPR (i.e., business management initiatives striving for process efficiency supported by IT) started to emerge and spread. ERP is a “framework for organizing, defining, and standardizing the business processes necessary to effectively plan and control an organization so the organization can use its internal knowledge to seek external advantage” (Blackstone and Cox 2005, p. 38). This dictionary definition resonates obviously with the expected outcomes of digitalization. The common aim/goal is to optimize organizations’ existing business processes through efficient coordination between routines (Pagani and Pardo 2017). Organizations may undertake a series of digitalization projects to automate processes and increase process efficiency (Bloomberg 2018).

For the practitioners, digitalization refers to “the use of digital technologies and data (digitized and natively digital) to create revenue, improve business, replace business processes (not simply digitizing them) and create an environment for digital business” (i-scoop 2016), and “using digital technologies to automate processes for better outcomes and to optimize value” (NCMM 2020). For scholars, digitalization refers to “the adoption of Internet-connected digital technologies and applications by companies” (Pagani and Pardo 2017, p. 185), and “a means to fulfill customers’ needs more effectively, adapt to changes in the sector and increase their competitive advantage” (Rachinger et al. 2019, p. 1150).

In digitalization, digital technologies serve as enablers for organizations to change their existing business processes (Verhoef et al. 2019), including communication

(Ramaswamy and Ozcan 2016; Van Doorn et al. 2010) and distribution (Leviäkangas 2016). To achieve such goals, organizations may use ERP or other digital technologies to support the digitalization process. The changes ERP introduced are primarily limited to business processes within organizational boundaries in efficiency improvement, cost reduction, and business process optimization (Ash and Burn 2003; Kauffman and Walden 2001), mainly focusing on deploying internal management information systems (Boersma and Kingma 2005). ERP and BPR put effort into exploiting IT software packages to improve organizational processes, focusing on production effectiveness and efficiency internally. Digitalization emphasizes the change process as a whole to achieve economic-driven outcomes through ERP or BPR and other digital technologies.

3.3 *Digital Transformation*

There is no common consensus regarding the seminal scientific definition of digital transformation in the literature. Historically, the ideas of digital products, services, and mediums can be traced back to the 1990s and 2000s (Auriga 2016; Schallmo et al. 2017). Morton (1991) noted that organizations experience fundamental transformations for effective IT implementation. This idea gave birth to a research stream studying IT-enabled organizational transformation, which may be seen as one of the scholarly roots of DT research (Nadkarni and Prügl 2020). It initiated DT's discussion with a strong IT focus as a catalyst of the information revolution (Gates et al. 1995) in the context of the Information Society's age and global competition. Therefore, at the early stage, a strong emphasis was put on the "digital" part – the use of digital technologies, providing a limited understanding of the "transformation" part of an entity. Thus, oftentimes, the concept of DT was used, or probably misused, synonymously with the one of digitization (the technical process) and digitalization (the installation process). With the accelerating development of digital technologies since the 1940s, industrial changes and societal developments throughout the previous decades could be witnessed, thus giving more importance to the transformational part of DT.

People then started to associate DT with the changes that digital technologies cause or influence in all aspects of human life (Stolterman and Fors 2004). The "transformation" part of DT, which was undervalued, gradually came back to attention. As different research streams started to emerge, some scholars gradually realized that DT is more than just a technological shift (Henriette et al. 2015). Apart from technology, it requires "actors" (Nadkarni and Prügl 2020) and the alignment of strategy and other factors, such as culture, mindset, talent development, and leadership (Goran et al. 2017). In recent years, some researchers have been concentrating on identifying DT's dimensions and drivers (Liere-Netheler et al. 2018a, b; Verhoef et al. 2019) as follows:

- **External drivers encompass:** (1) innovation push and market pull generated by the adoption and development of digital technologies (Nambisan et al. 2017; Sambamurthy et al. 2003); (2) increasing volume of data (Kouroubali and Katehakis 2019; Pappas et al. 2018; Zaki 2019); (3) accelerating customer behavior changes (Rogers 2016; von Leipzig et al. 2017; Westerman et al. 2014); and (4) laws/government policies adjustments (Gong et al. 2020; Nambisan et al. 2019), etc.
- **Internal drivers include:** (1) strategic imperative, such as, process and workplace improvement (Henriette et al. 2016); (2) vertical and horizontal integration (Camarinha-Matos et al. 2019; Gölzer and Fritzsche 2017; Borangiu et al. 2019; Liere-Netheler et al. 2018a, b); (3) management support (Matt et al. 2015; Vukšić et al. 2018); and (4) cost reduction (Liere-Netheler et al. 2018a, b), etc. Some other scholars focus on the positive and negative impacts of DT.
- **Positive consequences contain** (1) decision making improvement (Heilig et al. 2017; Roedder et al. 2016); (2) competitive advantage creation (Korhonen and Halen 2017; Schwertner 2017); (3) value creation enhancement, e.g., optimize customer experiences (Rogers 2016), etc.
- **Negative consequences cover** Cybersecurity (Möller 2020) and privacy (Mendhurwar and Mishra 2019), etc.

Beyond these new research directions, debates regarding the true nature of DT are ongoing. The controversy may be fundamentally founded in the fact that the range of DT definitions vary from: a slight technology-enabled change such as implementing a new ERP System (Chanas 2017) to a more radical and evolutionary process that takes place over time (Janowski 2015; Loebbecke and Picot 2015; Wang et al. 2018) or the economic and societal effects of digitization and digitalization (OECD 2018). While some researchers associate DT with business models (Berman 2012; Bharadwaj et al. 2013; Gassmann et al. 2014; Schallmo et al. 2017) and strategy (Bharadwaj et al. 2013; Henriette et al. 2015; Matt et al. 2015; Rogers 2016; Westerman 2018), others view DT as a paradigm or as a process (Berman 2012; Janowski 2015; Wang et al. 2018). As a result, the growing diversity of research fields associated with the concept of DT complexifies its clarification.

3.4 Synthesis

Historically, the three terms digitization, digitalization, and digital transformation are interconnected and describe different objects or phenomena. Digitalization with a longer history of use in the literature than digital transformation inevitably encompasses the early discussion of digitization's social impact and the later discussion of digital transformation's result. The absence of prevalent academic definitions for these three concepts is rooted in their ontogenesis, which was multivalent and parallel. Then, the multiplicity of connections between these concepts and others leads to a broad diversity of parallel theorizations. While this situation enriches the spectrum

of digital transformation research programs (Lakatos 1978), it does not clarify the concepts.

Multiple theorizations based on multiple conceptual definitions hinder the scientific community's ability to better define and connect all the objects involved in digital transformation, i.e., to standardize and generalize their research strategy. Therefore, the possibility of comparing different results from different studies is very limited in the current situation. It implies that authors of academic papers should first consider the connections applied between the chosen terms, the definitions, and the objects or phenomena under scrutiny.

Apart from its truly intended meaning, digitalization has also been used to describe digitization in some cases and digital transformation in other cases. Some authors such as Verhoef et al. (2019) view the terms in a sequential order (digitization → digitalization → digital transformation) with digitalization bridging and connecting the other two terms; other scholars disagree with this view. The situation is further complicated when linguistically translating digitalization and digital transformation as one word in some languages to explain the change and its end-results of using digital technologies, not the technical process.

Digitalization is used to depict a state of being digitalized and the process whereby the entities are affected by the action of “going digital.” Today's consensus seems that digital transformation is more than digitization (Haffke et al. 2016; Iansiti and Lakhani 2014; Yoo et al. 2012). According to a scoping review of Verhoef et al. (2019), most of the literature subscribes that digitization and digitalization imply more incremental phases to attain the most pervasive phase of digital transformation (Loebbecke and Picot 2015; Parviainen et al. 2017a, b). However, the inconsistent use of digitalization and digital transformation still exist in a broad range of academic and practitioner literature. And a disconcerting limitation of the existing literature is the failure to distinguish them properly.

4 The Concept Analysis Methodology

Based on Ogden and Richards (1923) semantic triangle (i.e., symbol, thought/reference, referent) and on Sartori's (1984) work (i.e., term/word, meaning, referent/object), Gerring (1999) proposed eight in-depth criteria of conceptual goodness: familiarity, resonance, parsimony, coherence, differentiation, depth, theoretical utility, and field utility. Gerring (1999) supports Ogden and Richards (1923) view that concepts are good when they attain a proper alignment between the three dimensions of intension, extension, and term (pp. 357–358) (see Fig. 2):

- **The term** refers to the words allocated to a concept as a label covering both the intension and the extension. It impacts the level of familiarity, resonance, and field utility of the concept.

Criteria	Explanation	Rating Scale					
Familiarity	The degree to which a new definition "makes sense," or is intuitively "clear," depends critically upon the degree to which it conforms/clashes with established usage.	0	1	2	3	4	5
		Definition clashes with established usage			Definition conforms with established usage		
Resonance	The "cognitive click" of a given term.	0	1	2	3	4	5
		No "cognitive click"	Low	Fair	Normal	High	Max "cognitive click"
Parsimony	The length of the definition (number of defining attributes) while concisely defining a concept.	0	1	2	3	4	5
		≥ 15 attributes	13-14	11-12	9-10	7-8	≤ 6 attributes
Coherence	The sense in which the attributes that define that concept, and the characteristics that actually characterize the phenomena in question, "belong to one another."	0	1	2	3	4	5
		Attributes are not logically or functionally related			Attributes are logically or functionally related		
Differentiation	It refers not only to semantic space (i.e., the degree to which a concept's definitional borders are clear) but also to physical space (i.e., the degree to which a concept's borders in time and space are clearly demarcated).	0	1	2	3	4	5
		No clear boundaries from/overlap with other concepts			Clear boundaries from other concepts; the concept is sufficiently bounded		
Depth	The depth and utility of a concept is enhanced by its ability to "bundle" characteristics. The greater the number of properties shared by the phenomena in the extension, the greater the depth of a concept.	0	1	2	3	4	5
		Limited number of properties shared by the phenomena			A great number of properties share by the phenomena		
Theoretical utility	The concept's usefulness in theory formulation (i.e., to formulate new theories or refine existing).	0	1	2	3	4	5
		Useless in theory formulation			Useful in theory formulation		
Field utility	The disruption that concept formation can do to the rest of the "semantic/phenomenal field" in which academic work.	0	1	2	3	4	5
		Damage the semantic field the concept enters			Enrich the conceptual quality of existing concepts in the field		

Fig. 2 Concept goodness assessment rating scale (Source Own illustration). *Notes* The eight criteria of concept goodness are adapted from Gerring (1999)

- **The intension**, i.e., connotation, meaning, definiens, or definition, refers to the properties or attributes that define a concept. The attributes specifically chosen to define the concept establishes its level of parsimony and internal coherence.
- **The extension**, i.e., denotation, referent, object, definiendum, refers to the object, event, or phenomenon to be defined and the referent or referents to which a concept applies. It determines the nature of the empirical cases a concept applies to and impacts the concept’s theoretical utility and depth. It determines a concept’s level of differentiation.

Exploring the evolution of definitions reveals: (1) the multiplicity of definitions proposed in the literature; (2) to what extent their defining attributes overlap between the three concepts: digitization, digitalization, and digital transformation; (3) the plurality of conceptual boundaries and therefore of realities under scrutiny. It allows specifying the core and peripheral defining attributes used to define the three concepts. The defining attributes can then be grouped to analyze their logical alignment (internal coherence) as well as their external differentiation. Hence, such an analytical process facilitates a qualitative evaluation regarding the connections between the three dimensions of the semantic triangle and assesses the conceptual goodness of the targeted concepts using a rating scale adapted from Gerring’s (1999) framework (see Fig. 2).

5 The Defining Attributes Analysis and Conceptual Assessment of the Relevant Terms in the Literature

5.1 Digitization

Definitions of digitization are collected until saturation/repetition of the defining attributes is observed. This process ensures that most of the applied defining attributes are identified. Saturation was achieved with 11 definitions. These key definitions of digitization evolved over the past two decades since the first definition was proposed in 1995 (and are presented in Appendix 2).

We summarize the 27 defining attributes of digitization and their frequency in Table 1. Based on the accumulated frequency of these attributes, the first five defining attributes are the core defining attributes (most frequent); the following 3 defining attributes are the peripheral (average frequency); and the rest are the outsiders (low frequency).

The analysis shows that digitization refers to a technical process of converting analog data/information¹ into digital forms. It is a process that has both symbolic (i.e., converting analog data into bits represented as 0 s and 1 s) and material (i.e., artifacts used to store and communicate digitized information) dimensions. Hence, through digitization, data is deconstructed and encoded as strings of 0 s and 1 s that “can then be expressed in many different ways, on many different types of materials, and in many different systems” (Brennen and Kreiss 2016, p. 2) as information. The ultimate characteristic of being stripped of errors, repetitions, and static allows digitized data and information to be easily stored, transferred, manipulated, and displayed, thus reducing paper clutter and improving efficiency. Digitization makes physical products programmable, addressable, sensible, communicable, memorable, traceable, and associable (Yoo 2010). Traditional physical products embedded with digital technologies, such as cameras (Tripsas 2009), phones (Ghazawneh and Henfridsson 2013), magazines (Nylén et al. 2014), and automobiles (Svahn et al. 2017), can provide a much wider range of functionality than non-digital products (Holmström 2018). The essence/essential meaning of digitization is presented in Fig. 3.

Based on the concept goodness assessment rating scale, digitization’s concept goodness is discussed as follows:

Familiarity: Digitization is rooted in the modern use of the verb “digitize” and refers to “the action or process of digitizing, i.e., the conversion of analog to digital forms.” If “digitization” as a whole word is not always very familiar for common people, the root “digit” and the suffix “-ization” are separately familiar. Such a level of familiarity here is enough to grasp the “conversion” nature of the term easily. However, in English, constructing a noun out of a verb by adding an “-ization” generates a double meaning (Taylor 2000). The new term will denote either the process described by the original verb or the end-state that results from the culmination of such a process (Buller and Gamble 2002). Therefore, common people can

¹ Note that data and information are used as synonyms in these definitions.

Table 1 Digitization's defining attributes and frequency

Concepts	Digitization									
	Negroponte (1995)	Yoo et al. (2010)	Katz and Koutroumpis (2013)	OED (2014)	Brennen and Kreiss (2016)	Legner et al. (2017)	Gölzer and Fritzsche (2017)	Schallmo and Williams (2018)	Bloomberg (2018)	Verhoef et al. (2019)
Defining attributes										
Analog	✓	✓	✓	✓	✓	✓		✓	✓	✓
Digital form/bits	✓	✓	✓	✓	✓	✓	✓		✓	✓
Process	✓		✓	✓	✓	✓		✓	✓	✓
Data/information	✓	✓	✓	✓	✓		✓		✓	✓
Conversion	✓		✓	✓	✓	✓				✓
Encoding		✓					✓		✓	
Technical	✓					✓				
Action				✓						✓
Transmit									✓	
Change										✓
Digitize				✓						
Physical artifacts								✓		
Store									✓	
Social			✓							
Transformation			✓							
Techno-economic environment			✓							

(continued)