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EDITED BY

Christothea Herodotou,
The Open University, United Kingdom

REVIEWED BY

Anthony Bokolo Jr.,
Institute for Energy Technology,
Norway
Christoph Meinel,
Hasso Plattner Institute, Germany

*CORRESPONDENCE

Gergana Vladova
Gergana.Vladova@wi.uni-potsdam.de

SPECIALTY SECTION

This article was submitted to
Digital Education,
a section of the journal
Frontiers in Education

RECEIVED 05 August 2022

ACCEPTED 22 November 2022

PUBLISHED 04 January 2023

CITATION

Dragičević N, Vladova G and Ullrich A
(2023) Design thinking capabilities
in the digital world: A bibliometric
analysis of emerging trends.
Front. Educ. 7:1012478.
doi: 10.3389/feduc.2022.1012478

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Design thinking capabilities in the digital world: A bibliometric analysis of emerging trends

Nikolina Dragičević¹, Gergana Vladova^{2,3*} and Andre Ullrich^{3,4}

¹Faculty of Economics and Business, University of Zagreb, Zagreb, Croatia, ²Research Group Education for the Digital World, Weizenbaum Institute for the Networked Society, Berlin, Germany, ³Chair of Business Informatics, Processes and Systems, University of Potsdam, Potsdam, Germany, ⁴Research Group Digitalization, Sustainability and Participation, Weizenbaum Institute for the Networked Society, Berlin, Germany

Recent research suggests that design thinking practices may foster the development of needed capabilities in new digitalised landscapes. However, existing publications represent individual contributions, and we lack a holistic understanding of the value of design thinking in a digital world. No review, to date, has offered a holistic retrospection of this research. In response, in this bibliometric review, we aim to shed light on the intellectual structure of multidisciplinary design thinking literature related to capabilities relevant to the digital world in higher education and business settings, highlight current trends and suggest further studies to advance theoretical and empirical underpinnings. Our study addresses this aim using bibliometric methods—bibliographic coupling and co-word analysis as they are particularly suitable for identifying current trends and future research priorities at the forefront of the research. Overall, bibliometric analyses of the publications dealing with the related topics published in the last 10 years (extracted from the Web of Science database) expose six trends and two possible future research developments highlighting the expanding scope of the design thinking scientific field related to capabilities required for the (more sustainable and human-centric) digital world. Relatedly, design thinking becomes a relevant approach to be included in higher education curricula and human resources training to prepare students and workers for the changing work demands. This paper is well-suited for education and business practitioners seeking to embed design thinking capabilities in their curricula and for design thinking and other scholars wanting to understand the field and possible directions for future research.

KEYWORDS

design thinking, digital technologies, digital transformation, capabilities, skills

Introduction

Although a relatively young scholarly discipline, design thinking (DT)—a human-centred approach that relies on how designers think and work (Brown, 2009; Johansson-Sköldberg et al., 2013)—proliferated in academic literature as a practice distinct from more traditional approaches to innovation and problem-solving in education and business. In this respect, DT is positioned as an “antidote to fossilised and ineffective management methods, rooted in practices that no longer serve organisations subject to dramatic and disruptive change” (Micheli et al., 2019, 144). Past research has shown that DT is beneficial for the development of capabilities of people and organisations to explore and solve wicked problems, innovate, or deal with uncertainty due to, for instance, its distinctive way of problem framing, human-centricity, integrative thinking and mindset open to alternatives (Carlgren et al., 2014; Gaim and Wåhlin, 2016; Beckman, 2020). Due to these benefits, companies and universities have made a case to embed DT throughout their curriculum as a way for non-designers to learn the value of DT practices, as highlighted in existing reviews (Micheli et al., 2019; Panke, 2019). Even with the occasional criticism of being too practitioner-oriented and having a dispersed theoretical foundation (Gaim and Wåhlin, 2016; Micheli et al., 2019), DT’s body of research and practice remains growing and relevant in innovation and management studies (Verganti et al., 2021).

Recent literature highlights the value of DT in developing employee capabilities in the digital world and calls for day-to-day research that will link the areas of DT and digital transformation both in business and education (e.g., Magistretti et al., 2021b; Kuo et al., 2022; Taimur and Onuki, 2022). Researchers see DT as valuable for dealing with ill-defined and wicked problems of digital transformations due to its ability to explore and act upon the opportunities of digital technologies by considering human needs and actively engaging them in the processes (Verganti et al., 2020; Magistretti et al., 2021b). In educational contexts, there is a potential for creating immersive learning experiences and experiential DT practices for solving relevant societal problems (Earle and Leyva-de la Hiz, 2021; de Waal and Maritz, 2022). Nevertheless, despite the conceptual and empirical appeal of utilising DT practices in this context, existing publications represent individual contributions and do not provide the trends in their entirety. While there are some relevant reviews related to the DT field (e.g., Micheli et al., 2019; Panke, 2019; Baker and Moukhliiss, 2020; Johann et al., 2020), they cover either characteristics of the DT field as a whole or include unique contexts not related to the digital world. We lack a holistic review which would provide an understanding of the value of DT capabilities relevant to the digital world.

In response, in this bibliometric review, we aim to shed light on the intellectual structure of the multidisciplinary DT

literature related to capabilities relevant to the digital world, highlight current trends and suggest further studies to advance theoretical and empirical underpinnings. In particular, we pose the following research questions: *What is the intellectual structure of the recent DT literature in the context of the digital world? Which DT capabilities, as observed in the examined literature, are relevant in the digital world?* We employ two bibliometric methods to pursue this research aim—bibliographic coupling and co-word analysis, as they are particularly suitable for identifying current trends and future research priorities at the forefront of the research (Vogel and Güttel, 2013; Zupic and Čater, 2015). Bibliometric methods are quantitative methods for describing, evaluating and monitoring scientific literature (Zupic and Čater, 2015). They allow us to assess the relative influence of the documents and how they cluster in the knowledge network, unveiling the commonalities in topics. We decided to focus on the business and higher education (HE) context as we were interested in assessing the contribution of the DT approach to future and current workers as active participants in digital transformation. Our results reveal several interrelated subfields of DT research related to capabilities development with and through digital technologies. Relatedly, DT becomes a relevant approach to be included in HE curricula and human resources (HR) training to prepare students and workers for the changing work demands.

Our analysis contributes to the theoretical development of DT literature by providing a holistic and objective review that uncovers the maturing of DT as a scientific discipline through differentiation and identity formation. Specifically, while past research has seen DT as “most intimately linked” to innovation (Dorst, 2011, p. 531), the focus becomes differentiated to include innovation at the crossroads of digital transformation, sustainability and various digital settings in education and business. Our findings also affirm the evolving of the DT academic field *via* identity formation—the understanding and recognition of common DT-related capabilities across different discourses. We uncover possible future research directions that include more diverse and rigorous methodologies and further theory development. Our findings complement currently existing reviews on DT by covering the scope so far not being investigated. This paper is well-suited for education and training practitioners seeking to embed DT practices in their curricula and DT and other scholars wanting to understand the field and possible directions for future research.

Background to the study

Design thinking practices and mindsets

Since its decontextualisation from a designerly context, DT has become a relevant concept in management and innovation

studies (Johansson-Sköldberg et al., 2013). The use of DT practices has been perceived to lead to more empathic mindsets and improved ways of dealing with challenges, for which traditional rational-analytical approaches are ill-fitted (Micheli et al., 2019). Consequently, educators have recognised the potential of teaching, learning and training DT practices in different fields, both in educational and business contexts, to equip students—future managers—with relevant workplace capabilities. DT particularly found its way in teaching creativity, problem-solving, innovation and entrepreneurship (Rauth et al., 2010; Glen et al., 2015; Johann et al., 2020). Essentially, apart from having something to do with outcomes (new ideas, better services), DT is said to have a more long-term effect on the capabilities, processes and mindsets of people and organisations which use it (Carlgren et al., 2014). Engaging in DT—due to the set of practices and mindsets that it employs, such as abductive thinking, (re)framing problems, diversity, human-centricity, iteration and experimentation, visualisation, and tolerance to ambiguity—is often associated with wicked problem-solving and innovation (Micheli et al., 2019). The summary of core DT themes and related practices is presented in **Table 1**.

Through its problem (re)framing and abductive reasoning, DT facilitates integrative thinking, which “seeks to find higher-order solutions that accommodate seemingly opposite forces” (Liedtka, 2015, 927). Others highlighted DT’s unique ability to combine intuitive and analytical thinking (Martin, 2010), or to combine thinking and doing, for instance, by building tangible visual devices and prototypes that help to facilitate fast learning through failure (Glen et al., 2015). Practical knowledge and competence are the essences of the DT work (Rylander, 2009), as noted early on by Buchanan (1992, p. 6): “designers are exploring concrete integrations of knowledge that will combine theory with practice for new productive purposes.” Beyond this practical learning component and the creation of usable knowledge, the literature notes that DT practices also can aid participants’ exploration connected with empathising and considering peoples’ values and needs. DT’s human-centred and user-driven practices are its core values (Liedtka, 2015). Further,

in DT practice, multiple stakeholders get involved: rather than to *design for*, the goal becomes to *design with* (Rowland, 2004). Engaging in co-creation is, therefore, another vital component of DT practices: an opportunity for an active, participatory role increases a sense of ownership of change and engagement (Glen et al., 2015).

Organisations in the digital world

Organisations are undergoing digital transformation, which aims to improve them “by triggering significant changes to [their] properties through combinations of information, computing, communication, and connectivity technologies” (Vial, 2019, 3). Digital technologies, such as the internet of things, big data, artificial intelligence, virtual and augmented reality or digital platforms, have transformative potential, radically altering how value is created. In business contexts, by bringing algorithms and automation to value co-creation, digital technologies may replace or augment human work and change the means of creating services and products (Vial, 2019; Brahma et al., 2020). In education, technological developments are driving demand redesigning learning spaces that would extend to digital environments (Latorre-Coscolluela et al., 2021). Digital technologies enable virtual learning environments, distant learning, or hybrid learning (Balyer and Öz, 2018; Pavlidou et al., 2021). The nature of digital work and learning becomes much more virtual and dynamic, allowing for more flexibility, autonomy, and new dynamics of experiences (Brahma et al., 2020; Verganti et al., 2020; Pavlidou et al., 2021).

With these digital transformation processes in organisations, numerous discussions are devoted to the skillsets and capabilities required to cope with technological and social change (Laar et al., 2020; Breque et al., 2021). According to the World Economic Forum Future of Jobs report (World Economic Forum [WEF], 2022), 50% of all employees will need reskilling by 2025 due to the growing role of digital technologies in the future of work. Despite recognising the need for technical skills, most of the reported relevant skills focus on soft aspects relying on human ingenuity, such as complex problem-solving, innovation, creativity, critical and analytical thinking, resilience, social influence, and leadership (World Economic Forum [WEF], 2022). Recent academic research also highlights the importance of nurturing human capabilities and soft skills in digital contexts, along with technical and ICT skills (e.g., Laar et al., 2020; Latorre-Coscolluela et al., 2021). Accordingly, education and business organisations are urged to develop curricula to prepare students and employees for changing demands of the future of workplaces with related capabilities. Practitioners and others need to create suitable new approaches or use existing ones in a targeted manner to achieve this goal.

TABLE 1 DT core practices/mindsets (adapted from Carlgren et al., 2016 and Dell’Era et al., 2020).

Theme	Practices/Mindsets
Human-centred design	Involving users; Empathising with humans
Problem framing	Framing and reframing; Abductive reasoning; Embracing ambiguity
Diversity	Engaging in integrative and holistic thinking; Interdisciplinary collaboration
Experimentation	Learning by doing; Failing often and soon; Diverging/Converging
Visualisation	Making ideas visual and tangible; Representing abstract concepts

Potential value of design thinking in the digital world

In education, research papers increasingly report opportunities for applying and teaching DT in digital contexts. DT practice potentially has much to offer in developing the capabilities required to cope with the challenges of digital transformation due to its ability to create proactive and responsible individuals who are critical, creative, and competent thinkers and creators (Pitkänen and Andersen, 2018; Earle and Leyva-de la Hiz, 2021). There is an understanding that the ability to deal with and through technologies is a critical part of society and working life. Accordingly, there is an opportunity to use DT with digital technologies to empower teachers and students with 21st-century skills and to solve relevant societal problems (Pitkänen and Andersen, 2018; Taimur and Onuki, 2022). DT, together with digital tools, provides a potential for more dynamic, immersive, and connected learning (Earle and Leyva-de la Hiz, 2021; Gleason and Cherrez, 2021; de Waal and Maritz, 2022).

It also becomes apparent that uncertainty and ambiguity associated with digital transformation, together with a need for a more resilient and sustainable society, are wicked problems that require “stepping outside of tried-and-true logics” (Cankurtaran and Beverland, 2020, 256), which DT practices may facilitate in business organisations. Further, to avoid technology fallacy (Kane, 2019), digital transformation requires alignment and integration of different components—technical, social, environmental, and human components (Anthony et al., 2021). In this sense, the DT perspective calls for a shift of focus from a merely technological or strategic perspective to include a human perspective at the centre of technological changes (Magistretti et al., 2021b; de Paula et al., 2022).

Whereas literature highlights the value of DT for digital transformation (e.g., Magistretti et al., 2021b; Kuo et al., 2022; Taimur and Onuki, 2022), we lack a holistic review of the studies discussing the value of DT-related capabilities in the digital world, which would uncover the trends at the forefront of the research in business and education.

Methodology

Bibliometric methods

Bibliometric methods use science mapping on bibliographic data from publication databases (e.g., Scopus or Web of Science) to detect the relative influence of publications and how they create knowledge clusters (e.g., major themes) in a network. In doing so, they can provide insights into the field’s evolution (i.e., its intellectual heritage) and the emerging areas of investigation (Donthu et al., 2021). Since performed

quantitatively and statistically using software (e.g., CiteSpace, Gephi, or VOSviewer), bibliographic methods tend to provide a more objective mean for deriving themes than manual reviews, mitigating in such a way the researcher bias (Zupic and Čater, 2015; Mukherjee et al., 2022). Standard methods include co-citation, bibliographical coupling, co-author, or co-word analysis.

In this paper, we leverage two of these methods—bibliographic coupling and co-word analysis—as they can aid us in identifying emerging trends in the DT field and future research directions (Zupic and Čater, 2015). A bibliometric method called *bibliographic coupling* analyses the association between cited articles (i.e., the overlap of the bibliographies between the publications) (Zupic and Čater, 2015). The method connects documents based on the number of references they share—the more the bibliographies of two papers overlap, the stronger their connection is. Based on the shared references among publications, bibliographic coupling assumes thematic similarity and, accordingly, forms clusters. In contrast to co-citation analysis, whose strength lies in mapping the intellectual heritage of a particular field based on high-impact publications, bibliographic coupling gives us an unbiased idea of interrelationships among temporary publications. It, therefore, highlights publication trends at the forefront of research (Vogel and Güttel, 2013). Since we were interested in uncovering current trends, bibliographic coupling was a suitable method.

To supplement the results of bibliographic coupling and improve its findings’ reliability (Glänzel and Czerwon, 1996), we also applied co-word analysis, a bibliometric analysis considered adequate for content analysis (Zupic and Čater, 2015). This method uses the (key)words within documents to establish relationships and to create a conceptual structure of a domain by assuming that words that frequently appear together (i.e., are clustered) have a thematic relationship with each other (Zupic and Čater, 2015; Donthu et al., 2021). Unlike co-citation and bibliographic coupling, which employ metadata for analysis, a co-word study examines the actual content of the publication. Consequently, the strength of the analysis lies in its ability to explore the prevalent topics in a research field. The co-word analysis usefully complements the results of bibliographic coupling by analysing the words in publications (and their relationships) to build a conceptual structure of the domain (Donthu et al., 2021).

Sampling

To identify relevant primary research papers, we searched the Web of Science (WoS) Core Collection database, the authoritative database in bibliometric research (Zupic and Čater, 2015), in May 2022. By using Boolean operators, we combined keywords describing the relationship between design

thinking (OR service design)¹ AND digital* (OR technolog*)² AND capabilities (OR skills OR competenc* OR abilities OR pedagogy OR education OR training OR learning OR teaching).³ We focused our search on documents published in journals (including reviews and early access papers) in the following scientific disciplines: business, management, education, educational research, engineering multidisciplinary, information science library science, and interdisciplinary sciences. We included a period of the last 10 years.

The initially retrieved documents contained 364 primary and 18,899 secondary, cited papers. Apart from DT HE and business managerial discourse, we have included other cases where DT is used in non-design contexts, for instance, engineering and healthcare. To check the match between the dataset and the research scope, we further read all the titles, abstracts and keywords (and, when necessary, full papers) and disregarded the documents which did not fit. Our initial review led to excluding papers not relevant to the research, for example, those dealing with the practice of designers, architects, and other arts-related disciplines. Finally, we included 99 primary and 5,477 secondary documents for the bibliographic coupling and co-word analysis using VoSviewer software [version 1.6.16 (0)] (Van Eck and Waltman, 2010). **Figure 1** provides an overview of the overall research process, consisting of four main steps.

Results

Bibliographic coupling

Using Vosviewer software (unit of analysis: documents, counting method: full counting), first, we performed a bibliographic coupling. We applied an additional filter by setting a threshold of 5 for minimum total link strength to exclude the papers with disconnected bibliographies. Total link strength indicates the total strength of bibliographic links of a given document with other documents. In the end, we included 85 papers that met this threshold to finalise the analysis.

VoSviewer analysis yielded four clusters (yellow, red, blue, and green in **Figure 2**). Each circle represents a document, and the closeness of the circles indicates how strongly documents are related to each other based on bibliographic coupling (Van Eck and Waltman, 2014). The closer two documents are located to each other in the visualisation, they tend to cite the same

publications and are therefore intellectually closer. **Table 2** provides an overview of the clusters and the most important papers weighted by the total link strength. Based on the full text of their most important papers, we named the clusters (1) Learning and digital classrooms, (2) Managerial capabilities, (3) Entrepreneurship and service, and (4) Organisational change.

Coupling cluster 1: Learning and digital classrooms

The dominant cluster (red) comprises 33 publications, the majority representing the area of education, including four out of the five most weighted papers. While the top-weighted paper by Reis et al. (2019) centres on the topic of entrepreneurship, the other four primary papers deal with the issues of DT pedagogy in the context of the development of 21st-century skills (Koh et al., 2015; Vallis and Redmond, 2021), university-business collaboration (Lee, 2019), and flipped class delivery (Das et al., 2019).

Other papers in the context of HE primarily focus on educational practice. Many of these introduce the results of case studies related, for instance, to the use of DT in new, virtual, or immersive learning environments (Davey et al., 2019; Fromm et al., 2021; Hasan et al., 2021). Quite a few papers are related to the characteristics inherent to using the DT approach in learning. These include, for example, critical and creative thinking (Šuligoj et al., 2020), self-directed learning (Avsec and Jagiełło-Kowalczyk, 2021), adaptive learning (Bower, 2016), transformative learning (Taimur and Onuki, 2022), problem-solving and teamwork mindset (Nguyen et al., 2021), often discussed in hybrid or virtual learning environments. These papers sometimes connect to theories such as Kolb's (1984) experiential learning theory, Deci and Ryan (2008) self-determination theory or Bandura's (1986) social cognitive theory. The cluster also includes educational contexts apart from business. For instance, one paper discusses the use of DT in medical education (Badwan et al., 2018) and two in the context of project-based learning STEM in engineering and computer science education (Kuo et al., 2019, 2022). Creativity is seen as a unique human skill required for future digital professionals (Vasilieva, 2018).

The cluster contains a highly quoted paper by Wrigley and Straker (2017), which offers interdisciplinary educational design ladder pedagogy and curriculum model for organisations to structure their DT programs that include online and face-to-face modes. Also relevant is a conceptual paper by Tsai et al. (2013) which discusses the essence of design epistemology, which is a “dynamic, collaborative and holistic aspect (...) of knowledge creation that yields useful practice, products, and services” that may be advanced with creative use of ICT. The journals are primarily representing outlets for educational research. The most important papers are published in journals such as Educational Technology & Society, Issues in Educational Research; Journal of University Teaching & Learning Practice;

1 We have included the term “service design” to cover those papers that refer to DT in service management context (Mejia et al., 2021), and disregarded those who base service design on other (non-DT) methods and principles.

2 We have used the keyword technolog* to cover immersive technologies and specific digital technologies by name (AI, machine learning, IoT, social media, etc.).

3 We have used these search terms to capture various nomenclature covering capabilities and ways of acquiring them.

TABLE 2 Top 5 most important papers for each cluster in the bibliographic coupling analysis.

Cluster	Author and year	Context	Description of the paper	Methodology	Weight
Cluster 1: Learning and digital classrooms	Reis et al. (2019)	Business/Engineering	This exploratory study investigates how entrepreneurs apply different approaches, including DT, for creating new businesses.	Survey-based research	201
	Lee (2019)	Education	The qualitative study presents an academic–industrial cooperation to revitalise a traditional street markets by using DT framework centred on creative and applied learning.	Interviews	118
	Koh et al. (2015)	Education	The paper identifies the 21st century learning dimensions and discusses how students can be guided in their learning experiences in these dimensions.	Conceptual	116
	Vallis and Redmond (2021)	Education	This study proposes DT as relevant approach to 21st century learning via its creative and collaborative complex problem solving and analyses business students’ DT activities with educational technologies.	Case study	98
	Das et al. (2019)	Education	The paper presents a case study in which DT is used as a framework for revamping teaching materials to be more student-centric.	Case study	96
Cluster 2: Managerial capabilities	Magistretti et al. (2021b)	Business	This paper proposes conceptualising and advancing DT as a dynamic capability for innovation rooted in lower-level aspects—microfoundations.	Systematic literature review	247
	Radnejad et al. (2022)	Business	The paper discusses how DT can assist firms in developing response strategies to disruptive innovations, along with effectively exploiting established technologies.	Case study	211
	Coco et al. (2020)	Education	The paper analyses a DT innovation journey, focusing on the struggles and triggers of participants as they work through conflicting demands in experiential learning.	Case study	208
	Earle and Leyva-de la Hiz (2021)	Education	This conceptual paper explores challenges found in sustainability-focused education and considers how the intersections of DT and emerging technologies can help address them.	Conceptual	192
	Magistretti et al. (2021a)	Business	The paper discusses how dynamic capabilities of design thinking foster discovering the opportunities digital technologies provide to enact the transformation.	Case study	184
Cluster 3: Entrepreneurship and service	Cooke et al. (2020)	Education	The paper proposes a framework that balances knowing with the thinking and doing of DT and implements it through a game design to increase students’ wicked problem solving skills in digital storytelling course.	Case study	107
	Laptev and Shaytan (2021)	Education	The paper develops a DT approach and identifies key characteristics for nurturing entrepreneurs in the digital age: creativity, analyticity, intuition, and flexibility of thinking.	Quasi-experimental	103
	Lugmayr et al. (2014)	Education	The paper describes the practical application of DT methodology in the Entertainment and Media Management Lab and presents some hands-on examples.	Case study	98
	Lynch et al. (2021)	Education	This exploratory study seeks to enhance understanding of teaching entrepreneurship to science and engineering students via DT pedagogy.	Case study	96
	Holeman and Kane (2020)	Health	The paper discusses how DT differs from conventional approaches to research and innovation in digital health initiatives by emphasising human-centricity, craft skills, and iterative methods.	Literature review, action research	95
Cluster 4: Organisational change	Beckman (2020)	Business	The paper investigates how DT practices fit with other approaches from which firms might choose to frame and solve problems (e.g., agile, lean startup) by investigating the basic capabilities underlying DT.	Theoretical	544
	Björklund et al. (2020)	Business	This qualitative paper analyses DT capabilities required to integrate the approach into organisations.	Interviews	526
	Drake (2017)	Education	The study investigates if innovative pedagogy using DT and ICT can help achieve better learning outcomes.	Case study	74
	Mirjamdotter et al. (2018)	Education	This case study reports about facilitation of student and stakeholder engagement in participatory design activities using soft systems methodology tools and techniques.	Case study	68
	Mubin et al. (2017)	Education	This paper presents a case study on DT-based education work in an industrial design honours program via multidisciplinary, technology and user-driven strategies.	Case study	66

Innovations in Education and Teaching International. The already mentioned top paper by [Reis et al. \(2019\)](#), however, is on entrepreneurship and not education, and the respective journal is IEEE Transactions on Engineering Management.

Coupling cluster 2: Managerial capabilities

The 28 documents in this cluster (green) are primarily conceptual and qualitative (case studies, interviews) papers related to the use of DT in business or management education contexts. The cluster includes evolving DT research within management discourse ([Johansson-Sköldberg et al., 2013](#)), expanding the scope beyond the predominant innovation and creativity focus to emerging digital areas.

Some of these papers stress the role of DT in managing conflicting demands and turbulent contexts both in business and educational contexts ([Schumacher et al., 2016](#); [Coco et al., 2020](#); [Magistretti et al., 2021b](#); [Radnejad et al., 2022](#)). DT is a critical practice to be included in HR and teaching slack for the new (digital) era related to talent management and learning (e.g., [Claus, 2019](#); [Guinan et al., 2019](#)). A few papers discuss the role of DT as a distinctive human sensemaking capability in contrast to the capabilities of AI and other digital technologies ([Verganti et al., 2020](#); [Dennehy et al., 2022](#)). [Verganti et al. \(2020\)](#) provided a meaningful discussion on the topic. They identified the advantages of both worlds and how they usefully complement each other. According to these authors, AI changes DT practices by replacing some of the capabilities previously done by people and overcoming some of their limitations. For instance, AI-powered DT can learn, adapt, and increase its scalability across organisational borders. It provides a foundation for user/human centricity by finding patterns based on large amounts of collected customer (or employee) data. Relatedly, the cluster contains an essential paper by [Liedtka \(2020\)](#) which theorises the role of DT as a technology facilitator and as a kind of social technology, a perspective which acknowledges innovation as a “shared process and ties it to human emotions and the complex ways people intersect and solutions emerge” (p. 54). The cluster also includes several papers on how DT can aid in reaching sustainability goals (e.g., [de Waal and Maritz, 2022](#); [Santa-Maria et al., 2022](#)).

Many papers (including top publications) aim to strengthen the tie between theory and managerial practice and to provide a theory-based foundation of DT by linking it with a range of theories, including dynamic capabilities ([Liedtka, 2020](#); [Magistretti et al., 2021b](#)), microfoundations ([Magistretti et al., 2021a](#)), behavioural strategy ([de Paula et al., 2022](#)), stakeholder theory ([Lievens and Blažević, 2021](#)), cognitive processes and strategic management ([Ospina and Sánchez, 2022](#)), HRM and innovation theory ([Claus, 2019](#)). [Magistretti \(Magistretti et al., 2020, 2021a,b\)](#) authors three papers in this cluster, including the top publication, underling his role in expanding the DT field to new digital contexts, particularly in connection to

dynamic capability development. The highly weighted papers are published in common management journals such as Creativity and Innovation Management Journal, Journal of Product Innovation Management and Industrial Marketing Management.

Coupling cluster 3: Entrepreneurship and service

Coupling cluster 3 (blue) consists of 18 publications primarily based on case studies. Like in the previous cluster, the use of DT in various educational contexts is a prevalent theme. The top publication is a case study by [Cooke et al. \(2020\)](#), which focuses on combining gamification and DT in education to increase students’ ability to solve wicked problems in a digital storytelling course. Other dominant documents focus on the possibilities of using DT for developing entrepreneurship skills in digital and technology intense environments ([Laptev and Shaytan, 2021](#); [Lynch et al., 2021](#)) and on applying DT in media management education ([Lugmayr et al., 2014](#)). This cluster also involves several papers on using DT in a medical context. For instance, these papers discuss DT in digital global health initiatives ([Holeman and Kane, 2020](#)), as well as creative and innovative solutions to emergent complex problems, particularly in training and patient care in the context of the COVID-19 pandemic ([Thakur et al., 2021](#)). These papers point out the importance of digital technology in these processes. Indicative is as well a sub-cluster revolving around DT in the service context. This sub-cluster includes topics such as teaching data-driven marketing ([Micheaux and Bosio, 2019](#)), designing smart energy solutions ([Willmott et al., 2022](#)), enabling participatory public service design ([Baek and Kim, 2018](#)), and as an innovation approach in technology start-ups ([Korper et al., 2020](#)).

Major articles in this cluster are published in various business and technology-related outlets such as Technological Forecasting and Social Change, Technical Communication Quarterly, Measuring Business Excellence and others. Service-related papers are published in journals such as the Journal of Marketing Education and the Journal of Service Theory and Practice. A relevant document by [Appleyard et al. \(2020\)](#), the only one from this cluster published in California Management Review, discusses the role of DT in building “creative forbearance” dynamic capability to regain market leadership in Siemens.

Coupling cluster 4: Organisational change

The two top publications in this smallest and more disconnected *cluster 4 (yellow)* are, at the same time, the most highly weighted papers overall. These two theoretical contributions were published in California Management Review and they, similarly to the documents in Cluster 2, are related to advancing DT managerial discourse. In particular, they address organisational change issues through the DT perspective. The

paper by Beckman (2020) uses experiential learning theory (Kolb, 1984) to understand DT practices of problem framing and solving and to relate them to similar approaches (e.g., critical thinking, lean, agile). The paper by Björklund et al. (2020) discusses the design capabilities required to integrate DT into organisations. These two publications, with their strong theoretical underpinning of the DT approach and positioning it to similar approaches, contribute to the continuation of the DT's development (and maturing) as an academic research/field. The other four publications focus on diverse applications of DT in the educational context, mainly stressing the role of DT in data- and technology-driven environments.

Co-word analysis

Using VOSviewer on the same dataset as for the bibliographic coupling (unit of analysis: full text, authors' keywords, title and abstract fields, counting method: full counting), we performed a co-word (content) analysis. We set the minimum number of keyword occurrences to 5, which yielded 120 items meeting the threshold. We additionally cleared the list from non-relevant and publication-related terms such as "literature review," "survey," and others, after which 82 items remained.

The co-word analysis yielded seven clusters depicting different themes (see Figure 3). The well-connected clusters deal with *learning and teaching* (cluster 1, red); *societal value* (cluster 2, green); *cognitive and behavioural aspects of DT* (cluster 3, blue); *service design and service innovation* (cluster 4, yellow); *impact across disciplines* (cluster 5, purple); *creating value through digital transformation* (cluster 6, light blue) and *change and organisational culture*; (cluster 7, orange). The themes covered by clusters confirm and further enrich the results of the bibliographic coupling analysis. We depict the 15 most weighted keywords across the clusters in Table 3 and all the keywords within the clusters in Supplementary Table 1. Change is a dominant keyword related to all relevant keywords from other clusters.

Coupling cluster 1: Learning and teaching

Creativity is a central theme of the dominant cluster (red), related to learning, teaching and pedagogy, which is not surprising given that DT-related skills and competencies are particularly relevant in educational contexts. Such a result is congruent with the bibliographic coupling analysis, reflecting a large corpus of papers dealing with this context. According to keywords in this cluster, DT is in education, especially concerned with learner autonomy and learning environments. Learning is as well highly associated with the topics of "work" and tangible "products," which echoes the strong practical relevance of the DT approach (Johansson-Sköldberg et al., 2013; Micheli et al., 2019). The cluster identifies empathy and ethical reasoning as aspects of DT practice.

TABLE 3 Fifteen most weighted keywords.

Keyword	Total link strength	Occurrences
Change	330	27
Business	238	19
Management	235	22
Creativity	231	34
Digital transformation	200	16
Impact	193	17
Value	174	19
Designer	168	16
Service design	167	10
Dynamic capability	157	12
Learner	145	21
Engineering	139	19
Service	137	11
Opportunity	130	13

Coupling cluster 2: Societal value

The second large cluster (green) deals with the societal value of DT, as employed by governments and other stakeholders to co-create services for citizens (Baek and Kim, 2018; Promsiri et al., 2022). A relevant topic is sustainability-related, and the most prevalent technology is virtual reality. The cluster also connects DT training topics to the labour market, indicating already *via* bibliographic coupling, identified the role of DT in talent management and the development of required capabilities for the future of work (e.g., Claus, 2019).

Coupling cluster 3: Cognitive and behavioural aspects

The third cluster (blue) investigates behavioural and cognitive aspects of using DT in business, particularly in management. Such themes are reflected in the papers such as de Paula et al. (2022), which identifies behavioural strategies conducive to DT in support of the creation of a managerial mental model or Ospina and Sánchez (2022), which links DT with behavioural strategy by investigating the relationship among design thinking personality traits, cognitive passive resistance and linear thinking. This cluster also connects DT to entrepreneurship, start-ups and engineering education (Reis et al., 2019; Laptev and Shaytan, 2021; Lynch et al., 2021).

Coupling cluster 4: Service design and service innovation

The fourth cluster (yellow) revolves around the DT for service design and service innovation *via* user-centred, participatory and co-design approaches that increase stakeholder engagement in business contexts. These topics are a part of the service management discourse of DT (Willmott et al., 2022). The cluster emphasises artificial intelligence as a

TABLE 4 Trends highlighting DT capabilities for the digital world.

Trends–relevant DT capabilities for digital world	Examples from the studied data	Integration: link with DT practices identified in the previous literature	Differentiation: recontextualization of existing DT practices
Empowering learners with and through digital technologies	<ul style="list-style-type: none"> • The capability of active, creative, collaborative, self-directed, experiential learning in virtual, or flipped learning environments (Das et al., 2019; Coco et al., 2020; Vallis and Redmond, 2021) • The capability of solving wicked problems in digital and sustainability education (Earle and Leyva-de la Hiz, 2021) 	<ul style="list-style-type: none"> • Involving users; Empathising with humans; Learning by doing; Failing often and soon; Diverging/Converging; Making ideas visual and tangible 	<ul style="list-style-type: none"> • E.g., new context of using digital technologies in sustainability education
Dynamic capabilities for innovation and digital transformation	<ul style="list-style-type: none"> • Dynamic capability of extending, debating, cropping, interpreting, and recombining to enable the digital transformation (Magistretti et al., 2021b) • DT sensing, seizing, and reconfiguring capabilities for innovation (Magistretti et al., 2021a; Liedtka, 2020) 	<ul style="list-style-type: none"> • Framing, Interdisciplinary collaboration, Integrative thinking; Involving users 	<ul style="list-style-type: none"> • E.g. DT practices form dynamic capabilities to foster digital transformation
Dealing with conflicting demands of digital transformation	<ul style="list-style-type: none"> • The capability of integrating perspectives, finding creative alternatives and synthesising (Schumacher and Mayer, 2018; Coco et al., 2020) • Capability to deal with competing tensions of exploitation and exploration (Radnejad et al., 2022) 	<ul style="list-style-type: none"> • Engaging in integrative and holistic thinking; Framing and reframing; Abductive reasoning 	<ul style="list-style-type: none"> • E.g., dealing with competing demands in support of innovation, managing turbulent contexts, and digital transformation
Bridging the human and technological worlds	<ul style="list-style-type: none"> • The capability to balance intuitive and analytical thinking (Verganti et al., 2021; Dennehy et al., 2022) • Sensemaking capability to make proper decisions regarding technology (Verganti et al., 2021) • The capability to bring human perspective and value to digital transformation and innovation (Liedtka, 2020; Magistretti et al., 2021b) 	<ul style="list-style-type: none"> • Engaging in integrative and holistic thinking; Interdisciplinary collaboration; Involving users; Empathising with humans; Framing and reframing 	<ul style="list-style-type: none"> • E.g., bridging the divide between human-centric and machine-centric activities
Connecting for service, societal value and sustainability	<ul style="list-style-type: none"> • The capability of wicked problems solving at the crossroad of technology and sustainability (de Waal and Maritz, 2022; Santa-Maria et al., 2022) • The capability of adopting multiple stakeholder perspectives, empathy and a service/Responsibility mindset and engaging stakeholders (Baek and Kim, 2018; Promsiri et al., 2022) 	<ul style="list-style-type: none"> • Interdisciplinary collaboration; Involving users; Empathising with humans; Engaging in integrative and holistic thinking; Representing abstract concepts 	<ul style="list-style-type: none"> • E.g., bringing broader societal value by enhancing the potential of (collaborative) innovative and entrepreneurial ecosystems
Facilitating interdisciplinarity	<ul style="list-style-type: none"> • The capability to integrate different disciplines in curricula (Kuo et al., 2019; Satpathy et al., 2020; Lynch et al., 2021) • The capability to integrate industry and academic perspectives (Boyle et al., 2022) 	<ul style="list-style-type: none"> • Interdisciplinary collaboration; Involving users; Engaging in integrative and holistic thinking; Learning by doing; Failing often and soon 	<ul style="list-style-type: none"> • E.g., advancing interdisciplinary collaboration and problem-solving by bringing different disciplines together in education

relevant for educators to include in HE curricula and HR training. Notably, to a considerable extent, the identified trends do not represent new aspects of DT-related practices and capabilities; instead, they fit ongoing discussion in DT literature, i.e., aid the identity formation of the field (see Table 4, column three). At the same time, the trends speak of the re-recontextualization of the existing knowledge on DT practices and related capabilities to various digital environments, therefore suggesting diversification of the DT field (see Table 4, column four). For instance, DT capability of wicked problem solving is studied in the new context of using digital technologies in sustainability education (Earle and Leyva-de la Hiz, 2021) and creativity in the contemporary context of enhancing the abilities of digital professionals (Vasilieva, 2018).

Co-word analysis further improved the reliability and enriched our bibliographic coupling analysis. Namely, the

identified themes were, to a large extent, consistent across the two studies. The analysis showed that management and creativity are still some of the prevailing themes in DT discourse, along with the emerging topic of digital transformation. Co-word analysis additionally highlighted the importance of DT capabilities for achieving sustainability and societal value in the digital world by forming a standalone cluster revolving around related topics (keywords). Further, “change” emerged as the most crucial keyword, suggesting that DT capabilities typically involve change by enabling new ways of working and value co-creation, causing disruption to activities, processes, and capabilities in digital transformation (de Paula et al., 2022). This is consistent with previous studies arguing that the introduction of the DT approach collides with the logic governing traditional educational and business systems and requires new mental models

and practices to be embedded (Elsbach and Stigliani, 2018; Cankurtaran and Beverland, 2020).

Trends

Empowering learners with and through digital technologies

Design thinking in education continues to be positioned as a viable option to overcome traditional educational systems' limitations. In this sense, aligned with previous literature (e.g., Glen et al., 2015), DT is deemed to be appropriate to support student-centricity, along with active and self-directed, experiential learning, collaboration, and creative thinking in classrooms (Das et al., 2019; Coco et al., 2020; Vallis and Redmond, 2021). The foci of education using DT is to nurture autonomous and empowered learners ("T-shaped" individuals, Brown, 2009) who can create practical knowledge and products that meet real-world needs (Coco et al., 2020). They can also tackle wicked problems associated with sustainability, medical care or accelerating digital growth (Earle and Leyva-de la Hiz, 2021; Thakur et al., 2021). Within this, DT is increasingly taught with and through digital technology, including digital platforms and more immersive technologies such as virtual and augmented reality (e.g., Earle and Leyva-de la Hiz, 2021; de Waal and Maritz, 2022). According to Tsai et al. (2013), digital technologies have the potential to foster DT epistemology and facilitate collaborative knowledge creation and juxtapositions of ideas *via* technological affordances.

Nevertheless, engaging in DT practice with and through digital technologies has some challenges, such as sustaining beyond COVID-19, risks associated with social isolation, lack of budget and knowledge to support education technologies, and lack of use of learning theories discussing DT practices in online contexts (Thakur et al., 2021; Vallis and Redmond, 2021).

Cultivating dynamic capabilities for innovation and digital transformation

The second research trend that we have recognised is a turn toward the dynamic capability perspective of DT. In particular, based on the dynamic capabilities literature (e.g., Teece et al., 1997), the managerial discourse of DT advances a view of DT as a dynamic capability for innovation and digital transformation. According to such a view, as stressed by Magistretti et al. (2021a), rather than serving a specific task, DT "plays a pivotal role in creating/improving the ability to repeatedly deal with wicked and ill-formulated innovation problems, from understanding intended/unintended market needs to actually developing innovation." These authors analyse microfoundations (i.e., lower level aspects such as characteristics, actions, and interactions, cf. Felin et al., 2012) of DT as the dynamic capability for innovation. Similarly,

Liedtka (2020) shows how DT aids with building dynamic capabilities essential for ongoing strategic adaptation and innovation. In another paper, Magistretti et al. (2021b) put forward that managers should cultivate DT dynamic capabilities of extending, debating, cropping, interpreting, and recombining to enable digital transformation.

Dealing with conflicting demands of digital transformation

A few papers that revolve around the managerial discourse of DT highlight its value in dealing with competing demands in support of innovation, managing turbulent contexts and digital transformation, both in education and business contexts (Schumacher and Mayer, 2018; Coco et al., 2020; Radnejad et al., 2022). In particular, DT is seen as a practical approach to the development of future managers because adopting related principles and practices can help them cope with resolving conflicting requirements, such as between exploitation of current digital technologies or creating new alternatives (Schumacher and Mayer, 2018; Coco et al., 2020; Magistretti et al., 2021b). This trend is congruent with some previous works which acknowledged the strength of DT in dealing with paradoxes as DT includes an integrative perspective and is characterised by abduction and reframing and an open-minded mindset that seeks to find creative alternatives and synthesising (Beverland et al., 2015; Gaim and Wählin, 2016). It is not, therefore, surprising that apart from creativity and innovation, DT has been associated with uncertain digital environments since "good designers can effectively tolerate the ambiguity and uncertainty that arises during inquiry" (Glen et al., 2015, p. 186).

On the organisational level, Radnejad et al. (2022) investigate how firms can cope with demands for disruptive technological innovation by simultaneously exploiting existing technologies. Past literature stresses that to cope with dynamic environments, organisations must find ways to deal with paradoxes and related tensions, such as balancing exploitation and exploration (March, 1991), efficiency and flexibility (Adler et al., 1999). We notice the continuation and expansion of this line of thinking, along with a proposition of using DT as a suitable option to facilitate these competing demands.

Bridging the human and technological worlds

Concerning the digital transformation of companies, it emerges that DT serves as a bridge between the human and technological worlds. For instance, a balance of analytical and intuitive thinking could bridge the divide between human-centric and machine-centric activities (Verganti et al., 2021; Dennehy et al., 2022). Despite the increasing automation, the inherently human part of DT remains a sensemaking capability that allows recognition of which problems should or should not be addressed or a framing capability that asks essential questions

about how digital technologies might change businesses by considering human values (Beckman, 2020; Holeman and Kane, 2020; Verganti et al., 2020). Humans have an essential role in capability building, as algorithms could never count for human irrationality (Liedtka, 2020).

Examined literature further highlights the critical role that employees (managerial and non-managerial) play in fostering digital transformation (e.g., Magistretti et al., 2021b; de Paula et al., 2022). The creation of a managerial mental model is needed to meet the challenges posed by digital transformation and the inclusion of perspectives of different involved stakeholders (Magistretti et al., 2021b; de Paula et al., 2022). This particularly seems important in digital health projects where DT promises to bring more humanised use of digital technologies through stakeholder participation, augmenting human skills, and attention to human values (Holeman and Kane, 2020). Such a position is consistent with previous studies putting forward that humans are the ones who have a crucial role in digitalisation since they are conveyors of (individual and organisational) learning about new technologies and strategies for utilising them (Sousa and Rocha, 2019; Blanka et al., 2022).

Connecting for service, societal value and sustainability

The role of DT in bringing broader societal value is reflected in research that centres on enhancing the potential of (collaborative) innovative and entrepreneurial ecosystems *via*, for instance, stimulating university-business collaborations (Lee, 2019; Jussila et al., 2020) and public service innovations (Baek and Kim, 2018; Promsiri et al., 2022). Within, these works put great emphasis on co-creation, multi-stakeholder engagement and empowerment across quadruple helix—academia, industry, public bodies, civil society, and citizens, together with the use of digital technologies. Second, educators and businesses use DT tools and principles to prompt conversations and create solutions to meet sustainability goals (de Waal and Maritz, 2022; Santa-Maria et al., 2022).

As sustainability and ethical issues are complex, intertwining different dimensions—social, technological, and environmental—and require empathy and practical solutions, researchers find that DT and associated capabilities may be suitable to cope with them (Tsai et al., 2013; Earle and Leyva-de la Hiz, 2021). The DT approach also has a bias toward service and responsibility (Rowland, 2004) and thus has found a fruitful ground for service and societal innovation. In this sense, we see a potential for DT to aid with bringing Industry 5.0, a transformative vision of a more sustainable, human-centric and resilient industry and society, to life (Breque et al., 2021). Progressing to Industry 5.0 aims at empowering workers by upskilling them with required digital and green skills and

developing human-centred technologies that consider users' needs and experiences.

Facilitating interdisciplinarity

In the context of HE, the critical issue is that developing relevant curricula requires interdisciplinary knowledge from different areas to help students develop the skills needed for bringing Industry 5.0 vision to realisation. In DT practice, interdisciplinary collaboration and problem-solving are advanced by bringing different disciplines together in education, for instance, business (and in particular entrepreneurship), engineering, STEM, and DT education (e.g., Kuo et al., 2019; Satpathy et al., 2020; Lynch et al., 2021). Another aspect of ensuring a competent future workforce is developing curricula by establishing university-industry collaboration (e.g., Boyle et al., 2022). The underlying logic is that establishing interdisciplinary and transdisciplinary knowledge can help address complexity, ensuring that a problem's technical, business, and human dimensions are addressed. Already Brown (2008, 86) noted how DT “uses the designer's sensibility and methods to match people's needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity.” Such an interdisciplinary view now does not include only DT business projects but also designing interdisciplinary curricula in education contexts.

Future research directions

More diverse and rigorous methodology

Design thinking field is traditionally very practice-oriented, which is not surprising given that the creation of practical knowledge is the essence of its epistemology (Tsai et al., 2013). It is not, therefore, unexpected that most of the publications covered by our analysis are empirical papers. Most of them are qualitative, out of which case study is the prevalent research method. We suggest future research to incorporate different methodologies and levels of analysis to bring more diversity and rigour to DT scientific discourse. For instance, from the bibliographic analysis, it becomes apparent that the contribution of the DT field to capability development in the digital era is analysed across levels, whether at the individual (e.g., cognition, behaviour, motivation, attention, self-perceptions), group (e.g., group creativity, engagement, change in the capacity for innovation in the group), or organisational level (e.g., culture change, organisational capability). However, apart from a microfoundational view on DT dynamic capability (Magistretti et al., 2021a), we have not found any other attempt at multilevel research. Such research could examine, for instance, how specific individual characteristics, skills and actions emerge to create organisational capabilities supporting (human-centric and sustainable) digital transformation using qualitative or quantitative means (Kozlowski et al., 2013).

Future DT studies would also benefit from using explorative qualitative studies, such as interview studies, focusing on examining DT capabilities' relevance for the digital world. Such studies may include exploring the challenges of specific contexts (business or educational) and examining the specific driving forces and outcomes of these compared to more traditional approaches to innovation and digital transformation. Finally, as a part of the empirical investigation of how DT practices are affected by the increasing use of digital technologies (Verganti et al., 2020), we recommend empirically examining the human-technology interaction and "mutual learning" opportunities. Such investigation may be done either through experimental or mix-method research designs.

Further theory development

While scholars view DT practices as a way to equip people with relevant capabilities for various digital transformation applications and provide relevant theoretical contributions, further theory development is required to support these benefits. We suggest a few streams as possible venues to strengthen the theory-based foundation of DT to become a scholarly discipline positioned as distinct from other more traditional approaches to navigating digital transformation and other societal challenges.

Several relevant papers from the bibliographic coupling decompose the underlying capabilities of DT, position these capabilities to other management and engineering approaches or discuss the capabilities required for DT-driven change in organisations (Beckman, 2020; Björklund et al., 2020). Nevertheless, these provide initial efforts, and further studies are needed to advance the underpinnings of such capability-based theoretical reasoning. There is also a need for advancing the dynamic and emergent capability view of DT in the education context, as focusing merely on static and specific competencies and skills may not adequately reflect students' capacity to act and deal with wicked problems (Phelps et al., 2005). Accordingly, future research efforts could be devoted to developing conceptual models of curriculum and pedagogy based on a dynamic view of DT capabilities. Such developments should be anchored in learning-related theories, such as Kolb's (1984) experiential learning theory, Deci and Ryan (2008) self-determination theory or Bandura's (1986) social cognitive theory.

One possible way to further explore the microfoundations of DT would be to adopt a practice lens based on the works of social theorists such as Giddens (1991) or Reckwitz (2002). A practice lens directs attention to what people do with particular digital technologies in their ongoing and situated activity. Our proposition is aligned with researchers who have already noted how the inherent logic and practices of DT provide a natural fit with practice theories (Kimbell, 2011) and called for a practice perspective for studying DT (Rylander et al., 2022). Next, we consider the DT approach relevant to the challenge of dealing with paradoxes embedded in digital environments (Dragičević et al., 2022). The capability to deal with paradoxical tensions and conflicting demands in business and education

contexts is often studied using the construct of an individual or organisational ambidexterity. We build on these premises to suggest that this theoretical stream may be complementary to the study of DT.⁴ Finally, due to the increasingly important role of digital technologies in DT practices, we recommend future research to investigate further the differences between human and machine design epistemologies and how they may complement each other.

Implications of research

Theoretical implications

This bibliometric study contributes to DT research by revealing the diversification of the DT field and its identity formation. While past research has seen DT capabilities as "most intimately linked" to innovation (Dorst, 2011, 531), the such focus becomes differentiated to include innovation at the crossroads with digital transformation or various digital settings where no innovation is necessarily involved in business and education contexts. The identity formation is reflected both in the continuity of the characteristics underlying DT capabilities (e.g., framing, diversity, experimentation, or human-centricity) as well as in their theoretical positioning to other approaches (e.g., lean, agile approaches) and related theories (e.g., stakeholder theory or dynamic capabilities). The study also complements previous reviews in the DT field by providing a bibliometric review to objectively identify knowledge clusters and interconnections across the examined literature (Mukherjee et al., 2022). Such a review may aid with understanding the knowledge development trends and future directions in the DT field related to the digital world, a focus that has not been investigated so far.

Practical implications

From a practical standpoint, bibliometric analyses help detect trends (behind descriptive findings) which may act as a ground for further examination and future research prospects based on the increased accountability in research governance (Mukherjee et al., 2022). Bibliographic coupling is especially valuable for identifying "hot research topics" since it also weights recently published papers that illustrate the early phases of a field's evolution (Glänzel and Czerwon, 1996). Aside from recognising beneficial research prospects, the practical value of

⁴ From the early use of the term of DT, it was associated with ambidexterity. For instance, Rolf Faste, one of the first contributors to development of DT discipline, noted that the aim of the course he created, titled "Ambidextrous thinking," was to encourage "a flexible and interdisciplinary way of working which abandons inappropriate mental barriers and stereotypes," and results in the "ability to combine and experiment with ideas in a fluent and flexible way" (Faste, 1994, p. 2).

identified trends may inform practitioners engaged in education and training development seeking to embed DT capabilities.

Limitations of the study

The study's first limitation relates more generally to the bibliometric methods (Vogel and Güttel, 2013). In bibliometric analysis, the context of why the authors include certain publications in the bibliography is missing; therefore, the interpretation of the clusters cannot count for the authors' intentions in citing. The analysis also overweighs more extensive bibliographies since the more citations the bibliography has, the greater the chances of overlaps with other bibliographies. The bibliographic coupling also weights papers by the shared bibliographies, thus neglecting the most cited articles in the field. Despite these shortcomings emerging from the authors' choices, the objectivity of discovering knowledge clusters is still considered one of the main advantages of the bibliometric methods (Mukherjee et al., 2022).

Moreover, the analysis might be impacted by a selection bias, as the authors identified the final data set. However, by defining and applying eligibility criteria, this bias should have been minimised. The presented transparency of the applied methodology allows the reader to assess the validity of the results, as they are reproducible. The final limitation of the study is related to the fact that the application of DT in the digital world continues to evolve as digitalisation attempts are ongoing rapidly. For these reasons, we have examined only short-term characteristics of the growing DT field concerning these areas; the more long-term changes may need re-evaluation in the following years.

Conclusion

In this paper, we examine the DT field's intellectual structure and relevant DT capabilities concerning the digital world using two (complementary) bibliometric methods: bibliographic coupling and co-word analysis. Our analysis of DT's publication and thematic patterns uncovers six trends describing areas describing DT capabilities required for the digital world and two possible future research directions. Overall, the evidence from this research supports the view that DT capabilities may play a relevant role in fostering more sustainable and human-centric digital transformation as advocated by recent research and industrial policies.

Data availability statement

The original contributions presented in this study are included in the article/**Supplementary material**, further inquiries can be directed to the corresponding author.

Author contributions

ND designed and performed the analysis. GV and AU assisted with the bibliometric data identification, cleaning, and analysis. ND wrote the manuscript in consultation with GV and AU. All authors contributed to the article and approved the submitted version.

Funding

This work was partly funded by the Federal Ministry of Education and Research of Germany (BMBF) under grant nos. 16DII137 and 16DII131 ("Deutsches Internet-Institut") and the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project no. 491466077.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2022.1012478/full#supplementary-material>

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