UNFOLDING DIGITAL DESIGN: A SYSTEMATIC REVIEW AND KEYWORD MAPPING ANALYSIS

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This study presents a systematic literature review of over 170 articles sourced from Scopus to explore the evolving field of digital design. Using VOSviewer for data mapping, we identified 17 key terms central to the discourse. These keywords were selected based on their frequency, relevance, and conceptual alignment with a definition-based analysis. By categorizing them, we reveal thematic clusters and interconnections that help clarify how digital design is framed and understood across publications. The novelty of this review lies in combining keyword mapping with conceptual categorization, offering a structured overview of the field. Our findings provide scholars and practitioners with a reliable foundation for future research and critical engagement with digital design.

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Introduction

In today's developed information society, we move beyond the traditional distinctions of online and offline, existing in an "Onlife" space that seamlessly merges analog and digital experiences. Indeed, the digital revolution has already occurred (Floridi, 2018). The widespread presence of digital phenomena in our design practices has become so routine and pervasive that we now refer to this entire range of phenomena as Digital Design (Oxman, 2006c).

Digital design can be broadly defined as the structured connection between information and representation methods that aid the design process in computational environments (Sass & Oxman, 2006). It involves generative processes connected to movement, and time is dynamic and not limited to rigid forms (Oxman, 2006a, 2006b). The key drivers of digital design are the processes of shaping, creating, and performance (Oxman, 2008). Indeed, Digital design introduces a new understanding of design beyond visually interpreting forms (Oxman, 2006a). In digital design, traditional concepts of paper-based representation are no longer effective for explaining the thinking and methods involved in the design process (Oxman, 2006b, 2006d, 2010). Many forms of creation now use emerging transformational processes, with digital media as the supportive environment (Oxman, 2006a). For instance, a design platform that enables the entire digital design process without the use of paper (Sass & Oxman, 2006). It also fosters intricate relationships between designers, users, digital tool developers, and design media. It is influenced by the design culture, including the introduction of new design methods. Since its inception, digital design has been growing and is supported by advancing technologies (Oxman, 2006d). The advancement of digital technologies facilitates new methods of design collaboration and enhances the interconnectedness between technology and design (Oxman, 2012). The development of digital design is a distinct area of design knowledge driven by new technologies, yielding a unique understanding of design (Oxman, 2010). Leading cloud service providers like Amazon Web Services, SalesForce, Rackspace, Joyent, Citrix, and VMware (Bharadwaj et al., 2013) have significantly contributed to this growth by providing platforms that enhance collaboration and accessibility in the design process.

Digital technology is now a powerful influence on design culture, reshaping how we represent, communicate, and create designs. It integrates media at every stage of the design process, from conceptualization to production, and has become widespread across all design fields. As it evolves rapidly, it's driving a fundamental shift in how design is understood and practiced. Additionally, digital design is becoming increasingly intertwined with virtual concepts as virtual environments continue to grow more immersive, knowledge-driven, and intelligent (Oxman, 2006c).

The number of prominent international projects designed using digital methods has grown significantly (Sass & Oxman, 2006). Digital technologies have had a considerable impact on design (Oxman, 2006a). They aid in the design process; for instance, computer modeling not only enables the creation of complex shapes but also serves as a bridge between design and construction, resulting in better quality in a shorter timeframe or the creation of rapid prototypes (Sass & Oxman, 2006). Digital interaction primarily relies on computer hardware, including a mouse, keyboard, and screen (Ma et al., 2003). The effective application of digital technology in design enhances artistic impact, overcoming the limitations of traditional models and improving efficiency for a better visual experience for the audience (Xiao, 2018). However, incorporating digital design and rapid prototyping tools into design education presents both benefits and challenges, such as the difficulty of teaching their use (Gu et al., 2010). Additionally, the abundance of diverse publications poses its challenges (Oxman, 2006a). Digital design is developing as a distinct field, influenced by its theories and discussions. This growth is leading to the emergence of new ideas, methods, and forms of expression (Oxman, 2006d).

Aligned with the study's objective to enhance our understanding of Digital design, we conducted research via Scopus, using the keyword search for "Digital design", and found 3,965 articles. Using VOSviewer, we analyzed data from bibliographic databases, including citations of authors, which helped us identify the leading authors in the field of Digital design. By considering the main authors and the total link strength, we identified the primary authors to proceed with this research as the main root of this study (see Figure 1 and Table 1).

Figure 1. Visualization of key authors using VOSviewer.

Table 1. Top 10 Main authors (Documents, Citations, and Total link strength)

No	Author	Documents	Citations	Total link strength
1	Oxman, R.	15	642	132
2	Abouzeid, F.	6	89	32
3	Autran, J.	4	50	32
4	Roche, P.	6	89	32
5	Badaroglu, M.	4	105	26
6	Donnay, S.	4	105	26
7	Liu, Y.	2	111	26
8	Butterfield, j.	3	70	24
9	Curran, r.	3	70	24
10	Daveau, J.	3	42	23

Note: 3,965 Scopus articles were analyzed, using VOSviewer to determine the central total link strength to identify key authors. In total, 10,063 authors were included, and the citation link strength between these authors was calculated.

To achieve our study objective, we encountered a limitation due to insufficient data from the top five authors, as much of their work focuses on technical aspects. This prompted us to explore beyond their publications. Consequently, we examined references cited in Oxman's papers (9 out of 11) that have a DOI (see Figure 2), as he was the primary author (with a total link strength of 132, as identified by VOSviewer), the only one whose work aligned closely with our objective. To further address the limitation, we also incorporated keyword definitions provided by the main authors.
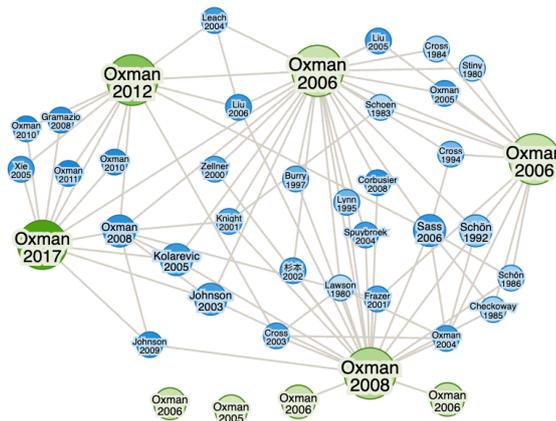

Figure 2. Visualization of Oxman's references used in this study via ResearchRabbitApp.com.

Overall, we found that there are numerous types of Digital design, including physical, virtual, and combinations of both, as well as designs that are built, not yet built, or impossible to build (Liu & Lim, 2006).

Related Keywords

Through our study of digital design, we identified 17 keywords relevant to this field (see Table 2). By applying the same method used in the digital design study, we identified the main authors and clarified the definitions of each keyword.

Table 2. Related Keywords (Total Articles on Scopus, And Main Authors)

No	Related keywords	Articles	Top authors
1	Digital artifacts	478	Keahey, K.; Anderson, J.; Kuhn, T.; Barnes, A
2	Digital citizenship	570	Choi, M.; Cristol, D.; Martin, F.; Glassman, M.
3	Digital culture	1172	Shifman, L.; Nissenbaum, A.; Alrasheedi, N.S.
4	Digital ecosystem	1277	Takizawa, M.; Enokido, T.; Aikebaier, A.
5	Digital ethics	2160	Floridi, L.; Cowls, J.; Chatila, R.; Luetge, C.
6	Digital infrastructures	1219	Sørensen, C.; Henfridsson, O.; Bygstad, B.
7	Digital innovation	1879	Lyytinen, K.; Yoo, Y.; Majchrzak, A.
8	Digital media	5910	Boulianne, S.; Bennett, W.L.; Reyna, J.
9	Digital objects	1232	Kallinikos, J.; Aaltonen, A.; Marton, A.
10	Digital platform	5143	Sørensen, C.; De Reuver, M.; Krcmar, H.
11	Digital services	2165	Chatterjee, S.; Rossi, M.; Williams, K.
12	Digital skills	1541	Van Deursen, A.J.A.M.; De Haan, J.
13	Digital sustainability	68	Abu-Tayeh, G.; Myrach, T.; Stuermer, M.
14	Digital system	5367	Kang, H. G.; Ivannikov, A.
15	Digital technology	25353	Vial, G.; Bharadwaj, A.; El Sawy, O.A.
16	Digital tools	2769	Colombo, G.; Terkaj, W.; Urgo, M.; Fleury, S.
17	Digitalization	16966	Parida, V.; Kääriäinen, J.; Tihinen, M.

Note: The top author is determined based on the total link strength found by VOSviewer

Keywords and definitions

Digital artifacts

Digital artifacts are created through digital technologies and result from coordinated human actions, lacking the stability and permanence of traditional objects (Eck et al., 2015; Kallinikos et al., 2013). A key feature of digital artifacts is that they are not standalone objects; instead, they are interconnected and often rely on broader digital ecosystems to function. These artifacts are flexible, editable, and can be modified continuously, distinguishing them from physical items (Kallinikos et al., 2013). However, they are vulnerable to loss due to data corruption or system malfunctions. Digital artifacts are shaped by technical elements and the social networks of individuals and institutions involved in their creation and use (Stuermer et al., 2017). Digital artifacts can be thought of as entities composed of binary code, which technical devices such as computers interpret to generate meaning. Examples of digital artifacts include files, images, and films or videos, which are fluid and editable, often integrated within complex, distributed, and dynamic digital environments (Kallinikos, 2009). To produce effective digital artifacts, it is crucial to have digital literacy skills (Reyna et al., 2018b).

Digital citizenship

Digital citizenship refers to the responsible and ethical use of digital technologies, encompassing knowledge and skills for appropriate online behavior (Choi et al., 2018; International Society for Technology in Education (ISTE), 2007; Martin et al., 2019, 2020; Mike S. et al., n.d.; Richardson et al., 2021). It involves four categories: Digital Ethics, Media and Information Literacy, Participation/Engagement, and Critical Resistance. It extends to creating and transforming communities, both online and offline, in the face of social injustice (Choi, 2016; Choi et al., 2017). Similar terms include online citizenship, cyber citizenship, technological citizenship, Internet citizenship, and networked citizenship (Choi, 2016).

Digital culture

Digital culture refers to the collection of values and practices that shape interactions among individuals, emphasizing adaptability during transformational processes. Core values such as transparency, support, stability, creativity, and collaboration play a critical role in this context (Alrasheedi et al., 2022). Notably, it is often said that: "Culture manifests in the absence of a leader" (Westerman et al., 2019, p. 60), indicating that unconscious behaviors exhibited by users can significantly impact cultural dynamics without direct leadership influence (Nissenbaum & Shifman, 2017, 2018; Shifman, 2013).

Digital ecosystem

A digital ecosystem refers to a network of interconnected digital systems, platforms, devices, and users that work together, exchange information, and support each other's functioning, creating a dynamic and collaborative environment (Boley & Chang, 2007; Briscoe, 2010; Briscoe et al., 2011; Briscoe & De Wilde, 2006; Eck et al., 2015; Marinos & Briscoe, 2009; Stuermer et al., 2017). It is information-centric, with user satisfaction as the ultimate performance measure reflecting a diverse range of evolving needs (Briscoe, 2010; Briscoe et al., 2011; Briscoe & De Wilde, 2006). Additionally, this ecosystem depends on interactions with others to enhance functionality, although challenges regarding environmental sustainability remain (Briscoe, 2010; Briscoe et al., 2011; Duolikun et al., 2013; Enokido et al., 2011; Enokido & Takizawa, 2012; Inoue et al., 2011; Marinos & Briscoe, 2009). In a broader context, it involves not only the technical components but also the social factors that influence its development and sustainability (Stuermer et al., 2017).

Digital ethics

Digital ethics, also known as computer, information, or data ethics, refers to the moral principles and frameworks that guide the responsible use of digital technologies, data, and algorithms, addressing issues such as data generation, processing, and usage (Floridi & Taddeo, 2016). It encompasses challenges like privacy, re-identification, group discrimination, and transparency, promoting trust and accountability in a data-driven world (Floridi & Taddeo, 2016; Milano et al., 2020). Digital ethics plays a crucial role in shaping regulations and governance, ensuring that technological developments align with socially acceptable and morally preferable standards (Floridi, 2018). In all areas of applied ethics, bioethics most closely resembles digital ethics, as both deal with new forms of agents, patients, and environments, drawing upon traditional principles such as beneficence, non-maleficence, autonomy, and justice (Floridi, 2013; Floridi et al., 2018).

Digital infrastructures

Research on the development of digital infrastructures is varied and fragmented (Koutsikouri et al., 2018). Digital infrastructures are interconnected system collectives that support modern service networks, such as social media and mobile phones, which require a global scale (Bygstad, 2017; Eaton et al., 2015), They encompass essential information technologies, organizational structures, and related services and facilities necessary for the functioning of enterprises and industries (Tilson et al., 2010, 2012). Digital infrastructure includes the computing and networking resources that enable various stakeholders to manage their service and content needs (Constantinides et al., 2018). These infrastructures are dynamic and continuously evolving to meet changing requirements, lacking distinct functions or fixed boundaries (Tilson et al., 2010). Comprising technology, users, and developers (Hanseth & Lyytinen, 2010), they function as socio-technical systems that facilitate information flow across various sectors, including health, transportation, and payments (Koutsikouri et al., 2018). Digital infrastructure theory emphasizes the installed technological base and its socio-technical network, focusing on standards and scalability (Bygstad & Øvrelid, 2020). These infrastructures evolve organically through innovation and scaling rather than traditional design (Bygstad, 2017).

Digital innovation

Digital innovation involves utilizing digital technologies to develop new products, services, and platforms, thereby enhancing customer experiences (Nambisan et al., 2017; Yoo et al., 2010). It integrates digital materiality into physical objects, transforming products and services (Yoo, 2013; Yoo et al., 2010). This process combines digital components in modular architectures to generate value (Huang et al., 2017) and follows phases such as ideation and virtualization (Lyytinen, 2022).

Digital media

Digital media relates to technologies that link to the Internet (Boulianne & Theocharis, 2020). It refers to content that is created, stored, and transmitted in digital format, including a wide range of formats and platforms, such as Websites, Social media platforms, Streaming services, and Digital advertisements. Digital media aims to effectively communicate information and engage with audiences across various platforms, fostering interaction, participation, and the sharing of experiences (Bennett & Segerberg, 2011) with all potentials and challenges it makes (Boulianne, 2020; Boulianne & Theocharis, 2020; Chang et al., 2015; Green et al., 2017). It enables the gathering and dissemination of information while also fostering and maintaining networks that support collective efforts to address social issues (Boulianne, 2020). The audiovisual domain pertains to the principles of Digital media (audio principles, layout design, color theory, typography, image/graphic, and video techniques) that guide the creation of compelling and trustworthy content (Reyna et al., 2018b).

Digital objects

Digital objects are networked entities dispersed across multiple platforms, lacking the completeness and stability of traditional objects (Kallinikos & Mariátegui, 2011). They are transient collections of data, activated through computer processes, and differ from physical artifacts due to their inherent potential for modification, such as a digital image that can be altered using graphic processing software (Márton, 2011; Sorapure, 2004). Digital objects, such as pixels, images, text, sounds, frames, and code, create new media objects (Sorapure, 2004). They function within a digital ecosystem, where their interactions are governed by the specific logic and rules of that environment. Consequently, other digital objects can only access, assemble, and manipulate them (Kallinikos et al., 2013).

Digital platform

A digital platform is a flexible, software-driven framework with an extensible codebase that supports third-party modules and enhances interactions between users and developers (De Reuver et al., 2018). It enables a wide range of services across various sectors, including social media, mobile operating systems, and peer-to-peer networks (Hein et al., 2020). Digital platforms transcend traditional business boundaries and foster innovation (Bharadwaj et al., 2013; Cenamor et al., 2019; Tilson et al., 2013). Examples include office software platforms like MS Office and Officestar, operating system platforms such as Windows and Unix, as well as application frameworks like ERP and CRM systems (e.g., SAP, Oracle, and SalesForce) and application development platforms like Service-Oriented Architecture (Hanseth & Lyytinen, 2010). Other well-known examples also include Airbnb, Uber, and Facebook (De Reuver et al., 2018). The platform should maintain an appealing simplicity, enabling designers to apply the significant skills they have developed through their experience with traditional media (Ma et al., 2003).

Digital services

Digital services refer to services acquired or organized through digital transactions involving information, software modules, or consumer goods over Internet Protocol (IP), a strict definition of digital service is "an activity or benefit that one party can give to another, provided through a digital transaction." (K. Williams et al., 2008). These services, embedded in or enabled by information and communication technologies (Lyytinen et al., 2016), utilize digital competencies through actions and processes that benefit other entities (Beverungen et al., 2017). While digital services may begin in the digital realm, interactions are not limited to it. Service providers aim to design these

offerings to achieve business, technological, and interaction success (K. Williams et al., 2008). Additionally, Digital services can derive from data related to physical products (Koldewey et al., 2019) and encompass both digitally deliverable goods and services, such as software sales and online education (L. D. Williams, 2021). Smart services, a specialized type, generate added value from product data (Frank et al., 2018).

Digital skills

Digital skills refer to the abilities required to effectively use the hardware and software of computers in the digital age (Helsper & Eynon, 2013; Reyna et al., 2018a; J. A. G. M. Van Dijk, 2012). Digital skills are viewed as essential for engaging in activities that enhance capital, achieving positive results from Internet use, and addressing issues of access and information inequality (J. A. G. M. ; Van Dijk & van Deursen, 2014). Moreover, technology plays a crucial role in determining which skills are valued. In the 21st century, digital skills involve mastering information and communication technology (ICT) tools to tackle cognitive tasks in the workplace, promoting higher-order thinking, continuous learning, and cognitive development. These skills include information management, communication, collaboration, critical thinking, creativity, and problem-solving abilities (Van Laar et al., 2017, 2018). Aligned with digital skills, 'digital literacy,' as introduced by (Gilster, 1998), refers to the ability to understand and use information from various digital sources (Van Laar et al., 2017).

Digital sustainability

Following the foundational concepts of sustainability outlined in the Brundtland Report (World Commission on Environment and Development, 1987, p. 37) Digital sustainability is the development and management of digital resources and artifacts aimed at enhancing environmental, social, and economic welfare while minimizing their negative impacts (Kotlarsky et al., 2023). It emphasizes the importance of adapting digital artifacts to meet the needs of current and future users, thereby improving their potential contribution to sustainable development (Stuermer et al., 2017). This approach relies on a balanced relationship between the ecosystem, digital literacy, and the responsible use of resources (Hilty & Aebischer, 2015; Stuermer et al., 2017). Furthermore, Digital sustainability encompasses various technological ecosystems, including mobile payment platforms, artificial intelligence, and blockchain, creating new opportunities for sustainable development (Konys, 2020).

Digital system

A digital system is composed of hardware and software layers that process information using binary values, aided by an analog-to-digital converter (Ivannikov, Kulagin, et al., 2016; Ivannikov, Romanov, et al., 2016; H. G. Kang et al., 2009; H.-G. Kang et al., 2009). This integration offers flexibility but also increases complexity and susceptibility to failures (H. G. Kang et al., 2009; H. G. Kang & Sung, 2002; H.-G. Kang et al., 2009).

Digital technology

Digital technology refers to the integration of systems, including information, computing, communication, and connectivity, through advancements in digital tools such as social media, mobile devices, analytics, and embedded devices (Vial, 2019). These technologies enable the transformation of business infrastructures, strategies, and relationships (Bharadwaj et al., 2013). It presents numerous opportunities but also comes with challenges and potential risks (Floridi, 2018).

Digital tools

Digital tools are software applications that enable the manipulation, analysis, and visualization of data to support various processes (Mahmood et al., 2021). For instance, Digital tools for media creation (Reyna et al., 2018b), provide access to and allow for the modification of internal data structures through file exchanges or application programming interfaces (Berardinucci et al., 2022). Additionally, they assist designers in their creative endeavors (Houzangbe et al., 2023).

Digitalization

Transforming analog information into digital format is known as digitalization (Mark et al., 2004). However, there is no consensus regarding the definition of digitalization. Parida defined digitalization as the use of digital technologies to innovate business models, generate new revenue streams, and create value-producing opportunities within industrial ecosystems, Digitalization is much more than applying technologies; it involves intelligence, connectivity, and analytics capabilities (Parida et al., 2019; Parida & Wincent, 2019). With all capabilities (Cenamor et al., 2017, 2019; Kohtamäki et al., 2019, 2020; Parida et al., 2019; Parviainen et al., 2022; Sjödin et al., 2018) and challenges (Briscoe, 2010; Duolikun et al., 2013; Enokido et al., 2011; Enokido & Takizawa, 2012; Inoue et al., 2011; Kohtamäki et al., 2019; Marinos & Briscoe, 2009; Parida et al., 2019; Parviainen et al., 2022; Sjödin et al., 2018, 2018). However, neglecting digitalization can have a significant impact on companies (Parida & Wincent, 2019). Digitization is promoted as a means to speed up the shift toward sustainability (George & Schillebeeckx, 2022).

Keywords categorization

A categorization and definition-based analysis approach was employed to effectively organize the digital concepts (see Figure 3). This method involved several key steps:

Identification of key terms: Relevant digital concepts were identified from the study, focusing on their definitions and significance within the digital design landscape.

Definition-based grouping: Each term was analyzed based on its definition, enabling the identification of key aspects, including scope, usage, and interrelationships. This approach facilitated an understanding of how each concept interacts within the digital realm.

Creation of categories: The identified terms were grouped into four distinct categories: Dimensions, Elements, Knowledge, and Technological. This categorization highlights the thematic connections between terms, enhancing comprehension of their roles in shaping digital experiences.
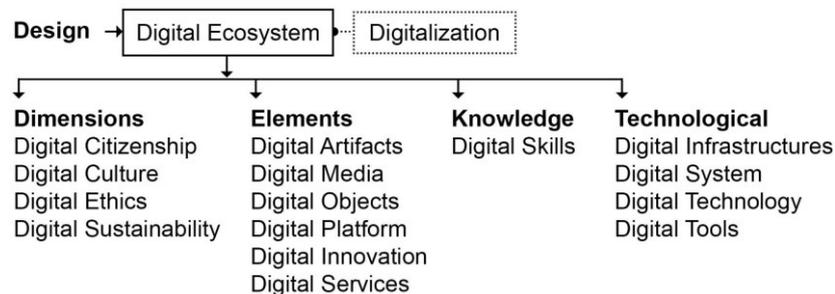

Figure 3. Categorization and definition-based analysis from our study findings.

The grouped terms are contextualized within the broader digital landscape, offering a cohesive understanding of how these concepts collectively shape our interaction with technology. This approach provides clearer insights into the interconnectedness of various digital ideas, fostering more informed discussions about the evolving digital environment.

Conclusion

Through an extensive literature review on Scopus and the application of data mapping techniques with VOSviewer, we identified Digital design as the process of creating digital visual content using digital tools and technologies, supported by digital infrastructure and systems that enable the creation, storage, and distribution of this content. Furthermore, we identified 17 related keywords aligned in this study, providing definitions for each by referencing the main authors associated with them. By adopting a systematic approach that incorporates categorization and definition-based analysis, we have organized key digital concepts into four primary categories:

Dimensions, Elements, Knowledge, and Technological. This classification highlights the interrelationships among these terms, enhancing our understanding of their roles in shaping digital experiences. By contextualizing these concepts within the broader scope of digital engagement, we offer a cohesive perspective on how they collectively influence interactions with digital technology. The insights gained from this research enrich academic discourse on digital design and serve as valuable resources for both practitioners and scholars.

References

Alrasheedi, N. S., Sammon, D., & McCarthy, S. (2022). Understanding the characteristics of workforce transformation in a digital transformation context. *Journal of Decision Systems*, *31*(sup1), 362–383. https://doi.org/10.1080/12460125.2022.2073636

Bennett, W. L., & Segerberg, A. (2011). Digital media and the personalization of collective action: Social technology and the organization of protests against the global economic crisis. *Information, Communication & Society*, *14*(6), 770–799. https://doi.org/10.1080/1369118X.2011.579141

Berardinucci, F., Colombo, G., Lorusso, M., Manzini, M., Terkaj, W., & Urgo, M. (2022). A learning workflow based on an integrated digital toolkit to support education in manufacturing system engineering. *Journal of Manufacturing Systems*, *63*, 411–423. https://doi.org/10.1016/j.jmsy.2022.04.003

Beverungen, D., Matzner, M., & Janiesch, C. (2017). Information systems for smart services. *Information Systems and E-Business Management*, *15*(4), 781–787. https://doi.org/10.1007/s10257-017-0365-8

Bharadwaj, A., El Sawy, O. A., University of Southern California, Pavlou, P. A., Temple University, Venkatraman, N., & Boston University. (2013). Digital Business Strategy: Toward a Next Generation of Insights. *MIS Quarterly*, *37*(2), 471–482. https://doi.org/10.25300/MISQ/2013/37:2.3

Boley, H., & Chang, E. (2007). Digital Ecosystems: Principles and Semantics. *2007 Inaugural IEEE-IES Digital EcoSystems and Technologies Conference*, 398–403. https://doi.org/10.1109/DEST.2007.372005

Boulianne, S. (2020). Twenty Years of Digital Media Effects on Civic and Political Participation. *Communication Research*, *47*(7), 947–966. https://doi.org/10.1177/0093650218808186

Boulianne, S., & Theocharis, Y. (2020). Young People, Digital Media, and Engagement: A Meta-Analysis of Research. *Social Science Computer Review*, *38*(2), 111–127. https://doi.org/10.1177/0894439318814190

Briscoe, G. (2010). Complex adaptive digital EcoSystems. *Proceedings of the International Conference on Management of Emergent Digital EcoSystems*, 39–46. https://doi.org/10.1145/1936254.1936262

Briscoe, G., & De Wilde, P. (2006). Digital Ecosystems: Evolving Service-Orientated Architectures. *2006 1st Bio-Inspired Models of Network, Information and Computing Systems*, 1–6. https://doi.org/10.1109/BIMNICS.2006.361817

Briscoe, G., Sadedin, S., & De Wilde, P. (2011). Digital Ecosystems: Ecosystem-Oriented Architectures. *Natural Computing*, *10*(3), 1143–1194. https://doi.org/10.1007/s11047-011-9254-0

Bygstad, B. (2017). Generative Innovation: A Comparison of Lightweight and Heavyweight IT. *Journal of Information Technology*, *32*(2), 180–193. https://doi.org/10.1057/jit.2016.15

Bygstad, B., & Øvrelid, E. (2020). Architectural alignment of process innovation and digital infrastructure in a high-tech hospital. *European Journal of Information Systems*, *29*(3), 220–237. https://doi.org/10.1080/0960085X.2020.1728201

Cenamor, J., Parida, V., & Wincent, J. (2019). How entrepreneurial SMEs compete through digital platforms: The roles of digital platform capability, network capability and ambidexterity. *Journal of Business Research*, *100*, 196–206. https://doi.org/10.1016/j.jbusres.2019.03.035

Cenamor, J., Rönnberg Sjödin, D., & Parida, V. (2017). Adopting a platform approach in servitization: Leveraging the value of digitalization. *International Journal of Production Economics*, *192*, 54–65. https://doi.org/10.1016/j.ijpe.2016.12.033

Chang, A.-M., Aeschbach, D., Duffy, J. F., & Czeisler, C. A. (2015). Evening use of light-emitting eReaders negatively affects sleep, circadian timing, and next-morning alertness. *Proceedings of the National Academy of Sciences*, *112*(4), 1232–1237. https://doi.org/10.1073/pnas.1418490112

Choi, M. (2016). A Concept Analysis of Digital Citizenship for Democratic Citizenship Education in the Internet Age. *Theory & Research in Social Education*, *44*(4), 565–607. https://doi.org/10.1080/00933104.2016.1210549

Choi, M., Cristol, D., & Gimbert, B. (2018). Teachers as digital citizens: The influence of individual backgrounds, internet use and psychological characteristics on teachers' levels of digital citizenship. *Computers & Education*, *121*, 143–161. https://doi.org/10.1016/j.compedu.2018.03.005

Choi, M., Glassman, M., & Cristol, D. (2017). What it means to be a citizen in the internet age: Development of a reliable and valid digital citizenship scale. *Computers & Education*, *107*, 100–112. https://doi.org/10.1016/j.compedu.2017.01.002

Constantinides, P., Henfridsson, O., & Parker, G. G. (2018). Introduction—Platforms and Infrastructures in the Digital Age. *Information Systems Research*, *29*(2), 381–400. https://doi.org/10.1287/isre.2018.0794

De Reuver, M., Sørensen, C., & Basole, R. C. (2018). The Digital Platform: A Research Agenda. *Journal of Information Technology*, *33*(2), 124–135. https://doi.org/10.1057/s41265-016-0033-3

Duolikun, D., Aikebaier, A., Enokido, T., & Takizawa, M. (2013). Energy-Aware Passive Replication of Processes. *Journal of Multimedia*, *9*(1), 53–65.

Eaton, B., Elaluf-Calderwood, S., London School of Economics and Political Science, Sørensen, C., London School of Economics and Political Science, Yoo, Y., & Temple University. (2015). Distributed Tuning of Boundary Resources: The Case of Apple's iOS Service System. *MIS Quarterly*, *39*(1), 217–243. https://doi.org/10.25300/MISQ/2015/39.1.10

Eck, A., Uebernickel, F., & Brenner, W. (2015). *The Generative Capacity of Digital Artifacts: A Mapping of the Field*. https://aisel.aisnet.org/pacis2015/231

Enokido, T., Aikebaier, A., & Takizawa, M. (2011). An Integrated Power Consumption Model for Communication and Transaction Based Applications. *2011 IEEE International Conference on Advanced Information Networking and Applications*, 695–702. https://doi.org/10.1109/AINA.2011.82

Enokido, T., & Takizawa, M. (2012). An Extended Power Consumption Model for Distributed Applications. *2012 IEEE 26th International Conference on Advanced Information Networking and Applications*, 912–919. https://doi.org/10.1109/AINA.2012.90

Floridi, L. (2013). *The Ethics of Information*. Oxford University Press.

Floridi, L. (2018). Soft ethics, the governance of the digital and the General Data Protection Regulation. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2133), 20180081. https://doi.org/10.1098/rsta.2018.0081

Floridi, L., Cowls, J., Beltrametti, M., Chatila, R., Chazerand, P., Dignum, V., Luetge, C., Madelin, R., Pagallo, U., Rossi, F., Schafer, B., Valcke, P., & Vayena, E. (2018). AI4People—An Ethical Framework for a Good AI Society: Opportunities, Risks, Principles, and Recommendations. *Minds and Machines*, *28*(4), 689–707. https://doi.org/10.1007/s11023-018-9482-5

Floridi, L., & Taddeo, M. (2016). What is data ethics? *Philosophical Transactions of the Royal Society A*, *374*. https://doi.org/10.1098/rsta.2016.0360

Frank, M., Koldewey, C., Rabe, M., Dumitrescu, R., Gausemeier, J., & Kühn, A. (2018). Smart services – Concept of a new market offering [Smart services – Konzept einer neuen marktleistung]. *ZWF Zeitschrift Für Wirtschaftlichen Fabrikbetrieb*, *113*(5), 306–311. https://doi.org/10.3139/104.111913

George, G., & Schillebeeckx, S. J. D. (2022). Digital transformation, sustainability, and purpose in the multinational enterprise. *Journal of World Business*, *57*(3), 101326. https://doi.org/10.1016/j.jwb.2022.101326

Gilster, P. (1998). *Digital literacy*.

Green, A., Cohen-Zion, M., Haim, A., & Dagan, Y. (2017). Evening light exposure to computer screens disrupts human sleep, biological rhythms, and attention abilities. *Chronobiology International*, *34*(7), 855–865. https://doi.org/10.1080/07420528.2017.1324878

Gu, N., Jones, W. M., & Williams, A. (2010). *Utilising digital design and rapid prototyping tools in design education*. 249–258. https://doi.org/10.52842/conf.caadria.2010.249

Hanseth, O., & Lyytinen, K. (2010). Design Theory for Dynamic Complexity in Information Infrastructures: The Case of Building Internet. *Journal of Information Technology*, *25*(1), 1–19. https://doi.org/10.1057/jit.2009.19

Hein, A., Schreieck, M., Riasanow, T., Setzke, D. S., Wiesche, M., Böhm, M., & Krcmar, H. (2020). Digital platform ecosystems. *Electronic Markets*, *30*(1), 87–98. https://doi.org/10.1007/s12525-019-00377-4

Helsper, E. J., & Eynon, R. (2013). Distinct skill pathways to digital engagement. *European Journal of Communication*, *28*(6), 696–713. https://doi.org/10.1177/0267323113499113

Hilty, L. M., & Aebischer, B. (2015). ICT for Sustainability: An Emerging Research Field. In L. M. Hilty & B. Aebischer (Eds.), *ICT Innovations for Sustainability* (Vol. 310, pp. 3–36). Springer International Publishing. https://doi.org/10.1007/978-3-319-09228-7_1

Houzangbe, S., Fleury, S., Masson, D., Jáuregui, D. A. G., Legardeur, J., Couture, N., & Richir, S. (2023). Exploration of Physiological Arousal in Divergent and Convergent Thinking using 2D screen and VR Sketching Tools. *2023 11th International Conference on Affective Computing and Intelligent Interaction (ACII)*, 1–8. https://doi.org/10.1109/ACII59096.2023.10388141

Huang, J., Henfridsson, O., Liu, M. J., & Newell, S. (2017). *Growing on steroids: Rapidly scaling the user base of digital ventures through digital innovation*. https://doi.org/10.25300/MISQ/2017/41.1.16

Inoue, T., Ikeda, M., Enokido, T., Aikebaier, A., & Takizawa, M. (2011). A Power Consumption Model for Storage-based Applications. *2011 International Conference on Complex, Intelligent, and Software Intensive Systems*, 612–617. https://doi.org/10.1109/CISIS.2011.101

International Society for Technology in Education (ISTE). (2007). *ISTE Standards for Teachers*. International Society for Technology in Education. http://www.iste.org/docs/pdfs/20-14_ISTE_Standards-T_PDF.pdf

Ivannikov, A., Kulagin, V., Romanov, A., & Pozdneev, B. (2016). Algebraic models of digital system design debugging decomposition. *2016 IEEE East-West Design & Test Symposium (EWDTS)*, 1–4. https://doi.org/10.1109/EWDTS.2016.7807712

Ivannikov, A., Romanov, A., & Stempkovsky, A. (2016). Set-theoretic model of digital systems functioning. *2016 International Siberian Conference on Control and Communications (SIBCON)*, 1–6. https://doi.org/10.1109/SIBCON.2016.7491726

Kallinikos, J. (2009). On the Computational Rendition of Reality: Artefacts and Human Agency. *Organization*, *16*(2), 183–202. https://doi.org/10.1177/1350508408100474

Kallinikos, J., Aaltonen, A., Hanken School of Economics, Marton, A., & Copenhagen Business School. (2013). The Ambivalent Ontology of Digital Artifacts. *MIS Quarterly*, *37*(2), 357–370. https://doi.org/10.25300/MISQ/2013/37.2.02

Kallinikos, J., & Mariátegui, J.-C. (2011). Video as Digital Object: Production and Distribution of Video Content in the Internet Media Ecosystem. *The Information Society*, *27*(5), 281–294. https://doi.org/10.1080/01972243.2011.607025

Kang, H. G., Lim, H. G., Lee, H. J., Kim, M. C., & Jang, S. C. (2009). Input-profile-based software failure probability quantification for safety signal generation systems. *Reliability Engineering & System Safety*, *94*(10), 1542–1546. https://doi.org/10.1016/j.ress.2009.02.018

Kang, H. G., & Sung, T. (2002). An analysis of safety-critical digital systems for risk-informed design. *Reliability Engineering & System Safety*, *78*(3), 307–314. https://doi.org/10.1016/S0951-8320(02)00176-X

Kang, H.-G., Kim, M.-C., Lee, S.-J., Lee, H.-J., Eom, H.-S., Choi, J.-G., & Jang, S.-C. (2009). An overview of risk quantification issues for digitalized nuclear power plants using a static fault tree. *Nuclear Engineering and Technology*, *41*(6), 849–858. https://doi.org/10.5516/NET.2009.41.6.849

Kohtamäki, M., Parida, V., Oghazi, P., Gebauer, H., & Baines, T. (2019). Digital servitization business models in ecosystems: A theory of the firm. *Journal of Business Research*, *104*, 380–392. https://doi.org/10.1016/j.jbusres.2019.06.027

Kohtamäki, M., Parida, V., Patel, P. C., & Gebauer, H. (2020). The relationship between digitalization and servitization: The role of servitization in capturing the financial potential of digitalization. *Technological Forecasting and Social Change*, *151*, 119804. https://doi.org/10.1016/j.techfore.2019.119804

Koldewey, C., Evers, H. H., Dumitrescu, R., Frank, M., Gausemeier, J., & Reinhold, R. (2019). *Development process for smart service strategies: Grasping the potentials of digitalization for servitization*. Proceedings of The XXX ISPIM Innovation Conference.

Konys, A. (2020). How to support digital sustainability assessment? An attempt to knowledge systematization. *Procedia Computer Science*, *176*, 2297–2311. https://doi.org/10.1016/j.procs.2020.09.288

Kotlarsky, J., Oshri, I., & Sekulic, N. (2023). Digital Sustainability in Information Systems Research: Conceptual Foundations and Future Directions. *Journal of the Association for Information Systems*, *24*(4), 936–952. https://doi.org/10.17705/1jais.00825

Koutsikouri, D., Lindgren, R., Henfridsson, O., & Rudmark, D. (2018). Extending digital infrastructures: A typology of growth tactics. *Journal of the Association for Information Systems*, *19*(10). https://aisel.aisnet.org/jais/vol19/iss10/2

Liu, Y.-T., & Lim, C.-K. (2006). New tectonics: A preliminary framework involving classic and digital thinking. *Design Studies*, *27*(3), 267–307. https://doi.org/10.1016/j.destud.2005.11.008

Lyytinen, K. (2022). Innovation logics in the digital era: A systemic review of the emerging digital innovation regime. *Innovation*, *24*(1), 13–34. https://doi.org/10.1080/14479338.2021.1938579

Lyytinen, K., Yoo, Y., & Boland Jr., R. J. (2016). Digital product innovation within four classes of innovation networks. *Information Systems Journal*, *26*(1), 47–75. https://doi.org/10.1111/isj.12093

Ma, Y.-P., Lee, C.-H., & Jeng, T. (2003). *Inavigator: A Spatially-Aware Tangible Interface for Interactive 3D Visualization*. 963–974. https://doi.org/10.52842/conf.caadria.2003.963

Mahmood, K., Otto, T., Kuts, V., Terkaj, W., Modoni, G., Urgo, M., Colombo, G., Haidegger, G., Kovacs, P., & Stahre, J. (2021). Advancement in production engineering education through Virtual Learning Factory Toolkit concept. *Proceedings of the Estonian Academy of Sciences*, *70*(4), 374. https://doi.org/10.3176/proc.2021.4.02

Marinos, A., & Briscoe, G. (2009). Community Cloud Computing. In M. G. Jaatun, G. Zhao, & C. Rong (Eds.), *Cloud Computing* (Vol. 5931, pp. 472–484). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-10665-1_43

Mark, E., Oxman, R., Kvan, T., Mark, E., Oxman, R., & Martens, B. (2004). *Ditching the Dinosaur: Redefining the Role of Digital Media in Education*.

Martin, F., Gezer, T., & Wang, C. (2019). Educators' Perceptions of Student Digital Citizenship Practices. *Computers in the Schools*, *36*(4), 238–254. https://doi.org/10.1080/07380569.2019.1674621

Martin, F., Hunt, B., Wang, C., & Brooks, E. (2020). Middle School Student Perception of Technology Use and Digital Citizenship Practices. *Computers in the Schools*, *37*(3), 196–215. https://doi.org/10.1080/07380569.2020.1795500

Márton, A. (2011). The Transfigurability of Digital Objects. *Artnodes*, *0*(10). https://doi.org/10.7238/a.v0i10.1079

Mike S., R., Gerald D., B., & Tweed W., R. (n.d.). Digital Citizenship: Addressing Appropriate Technology Behavior. *Learning & Leading with Technology*. http://www.iste.org/standards/

Milano, S., Taddeo, M., & Floridi, L. (2020). Recommender systems and their ethical challenges. *AI & SOCIETY*, *35*(4), 957–967. https://doi.org/10.1007/s00146-020-00950-y

Nambisan, S., Lyytinen, K., Case Western Reserve University, Majchrzak, A., University of Southern California, Song, M., & Xi'an Technological University. (2017). Digital Innovation Management: Reinventing Innovation Management Research in a Digital World. *MIS Quarterly*, *41*(1), 223–238. https://doi.org/10.25300/MISQ/2017/41:1.03

Nissenbaum, A., & Shifman, L. (2017). Internet memes as contested cultural capital: The case of 4chan's /b/ board. *New Media & Society*, *19*(4), 483–501. https://doi.org/10.1177/1461444815609313

Nissenbaum, A., & Shifman, L. (2018). Meme Templates as Expressive Repertoires in a Globalizing World: A Cross-Linguistic Study. *Journal of Computer-Mediated Communication*, *23*(5), 294–310. https://doi.org/10.1093/jcmc/zmy016

Oxman, R. (2006a). *Digital design thinking: In the new design is the new pedagogy*. 37–46. https://doi.org/10.52842/conf.caadria.2006.x.g3r

Oxman, R. (2006b). *Educating the Digital Design Thinker—What Do We Teach When We Teach Design*. 198–205. https://doi.org/10.52842/conf.ecaade.2006.198

Oxman, R. (2006c). Special Issue of Design Studies on Digital Design. *Design Studies*, *27*(3), 225–227. https://doi.org/10.1016/j.destud.2005.11.003

Oxman, R. (2006d). Theory and design in the first digital age. *Design Studies*, *27*(3), 229–265. https://doi.org/10.1016/j.destud.2005.11.002

Oxman, R. (2008). Digital architecture as a challenge for design pedagogy: Theory, knowledge, models and medium. *Design Studies*, *29*(2), 99–120. https://doi.org/10.1016/j.destud.2007.12.003

Oxman, R. (2010). Sharing media and knowledge in design pedagogy, Special Issue Advanced Digital Technologies for Built Environment Education and Learning. *Journal of Information Technology in Construction (ITcon)*, 291–305. http://www.itcon.org/2010/22

Oxman, R. (2012). Informed tectonics in material-based design. *Design Studies*, *33*(5), 427–455. https://doi.org/10.1016/j.destud.2012.05.005

Parida, V., Sjödin, D., & Reim, W. (2019). Reviewing Literature on Digitalization, Business Model Innovation, and Sustainable Industry: Past Achievements and Future Promises. *Sustainability*, *11*(2), 391. https://doi.org/10.3390/su11020391

Parida, V., & Wincent, J. (2019). Why and how to compete through sustainability: A review and outline of trends influencing firm and network-level transformation. *International Entrepreneurship and Management Journal*, *15*(1), 1–19. https://doi.org/10.1007/s11365-019-00558-9

Parviainen, P., Tihinen, M., Kääriäinen, J., & Teppola, S. (2022). Tackling the digitalization challenge: How to benefit from digitalization in practice. *International Journal of Information Systems and Project Management*, *5*(1), 63–77. https://doi.org/10.12821/ijispm050104

Reyna, J., Hanham, J., & Meier, P. (2018a). The Internet explosion, digital media principles and implications to communicate effectively in the digital space. *E-Learning and Digital Media*, *15*(1), 36–52. https://doi.org/10.1177/2042753018754361

Reyna, J., Hanham, J., & Meier, P. C. (2018b). A framework for digital media literacies for teaching and learning in higher education. *E-Learning and Digital Media*, *15*(4), 176–190. https://doi.org/10.1177/2042753018784952

Richardson, J. W., Martin, F., & Sauers, N. (2021). Systematic review of 15 years of research on digital citizenship: 2004–2019. *Learning, Media and Technology*, *46*(4), 498–514. https://doi.org/10.1080/17439884.2021.1941098

Sass, L., & Oxman, R. (2006). Materializing design: The implications of rapid prototyping in digital design. *Design Studies*, *27*(3), 325–355. https://doi.org/10.1016/j.destud.2005.11.009

Shifman, L. (2013). Memes in a Digital World: Reconciling with a Conceptual Troublemaker. *Journal of Computer-Mediated Communication*, *18*(3), 362–377. https://doi.org/10.1111/jcc4.12013

Sjödin, D. R., Parida, V., Leksell, M., & Petrovic, A. (2018). Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing *Moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies. Research-Technology Management*, *61*(5), 22–31. https://doi.org/10.1080/08956308.2018.1471277

Sorapure, M. (2004). *Five Principles of New Media: Or, Playing Lev Manovich*.

Stuermer, M., Abu-Tayeh, G., & Myrach, T. (2017). Digital sustainability: Basic conditions for sustainable digital artifacts and their ecosystems. *Sustainability Science*, *12*(2), 247–262. https://doi.org/10.1007/s11625-016-0412-2

Tilson, D., Lyytinen, K., & Sørensen, C. (2010). Digital Infrastructures: The Missing IS Research Agenda. *Information Systems Research*, *21*(4), 748–759. https://doi.org/10.1287/isre.1100.0318

Tilson, D., Sorensen, C., & Lyytinen, K. (2012). Change and Control Paradoxes in Mobile Infrastructure Innovation: The Android and iOS Mobile Operating Systems Cases. *2012 45th Hawaii International Conference on System Sciences*, 1324–1333. https://doi.org/10.1109/HICSS.2012.149

Tilson, D., Sorensen, C., & Lyytinen, K. (2013). Platform Complexity: Lessons from the Music Industry. *2013 46th Hawaii International Conference on System Sciences*, 4625–4634. https://doi.org/10.1109/HICSS.2013.449

Van Dijk, J. A. G. M. (2012). *The evolution of the digital divide: The digital divide turns to inequality of skills and usage*. 57–64. https://doi.org/10.3233/978-1-61499-057-4-57

Van Dijk, J. A. G. M. ;, & van Deursen, A. J. A. M. (2014). *Digital Skills, Unlocking the Information Society*. Palgrave Macmillan.

Van Laar, E., Van Deursen, A. J. A. M., Van Dijk, J. A. G. M., & De Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Van Laar, E., Van Deursen, A. J. A. M., Van Dijk, J. A. G. M., & De Haan, J. (2018). 21st-century digital skills instrument aimed at working professionals: Conceptual development and empirical validation. *Telematics and Informatics*, *35*(8), 2184–2200. https://doi.org/10.1016/j.tele.2018.08.006

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Westerman, G., Soule, D. L., & Eswaran, A. (2019). *Building Digital-Ready Culture in Traditional Organizations*. *60*(4), 59–68.

Williams, K., Chatterjee, S., & Rossi, M. (2008). Design of emerging digital services: A taxonomy. *European Journal of Information Systems*, *17*(5), 505–517. https://doi.org/10.1057/ejis.2008.38

Williams, L. D. (2021). Concepts of Digital Economy and Industry 4.0 in Intelligent and information systems. *International Journal of Intelligent Networks*, *2*, 122–129. https://doi.org/10.1016/j.ijin.2021.09.002

World Commission on Environment and Development. (1987). *Report of the World Commission on Environment and Development: Our common future*.

Xiao, W. (2018). New Concept of Visual Communication Design in the Digital Age. *2018 4th International Conference on Education & Training, Management and Humanities Science (ETMHS 2018)*. 2018 4th International Conference on Education & Training, Management and Humanities Science. https://doi.org/10.23977/etmhs.2018.29131

Yoo, Y. (2013). The Tables Have Turned: How Can the Information Systems Field Contribute to Technology and Innovation Management Research? *Journal of the Association for Information Systems*, *14*(5), 227–236. https://doi.org/10.17705/1jais.00334

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research. *Information Systems Research*, *21*(4), 724–735. https://doi.org/10.1287/isre.1100.0322