New Design Knowledge and the Fifth Order of Design

Marzia Mortati

Introduction

As human habits are transformed by new technologies (e.g., data-driven and self-learning technologies) and renovated societal concerns (e.g., sustainability and the green transition, sustainable development goals [SDGs], and the global pandemic), design is increasingly confronted with new and critical questions. These questions range from how to master disruptive technologies that seem more challenging than in the past, to how to use systemic thinking to deal competently with the green and digital transitions. Despite limits and criticalities, design appears to be one of the significant professions of time, because of its capability in meeting challenges that not only are technical but also creative and social.[1] This emerging recognition in some areas is beginning to complement the centrality of economic models and management-led efficient rationality[2]; as a result, the design discipline might now rise to play the critical role it has always wanted to play, building bridges between technological research, ethical and socio-cultural responsibilities, and innovation. Several scholars and practitioners have already described and examined the role design can have when bridging technology, innovation, and people, both in theory and project-based activities.[3] However, design is often described as marginal in innovation frameworks. Its role has been confined to the later stages of the development spectrum, often limited to beautifying solutions or making them more usable and engaging for people. Reflections on ethical responsibilities have often remained marginal for designers in practice because of the obligations dictated by the business models that drive design work. But with a broader attempt to include creativity and culture as drivers of sustainable development, new opportunities might emerge for design to prove its relevance for society (e.g., helping to build a stronger sense of belonging and well-being).[4]

Given the myriad challenges linked to being ready to take on these responsibilities, scholars reflect on the knowledge that designers need to help address twenty-first-century challenges. Design literature advocates for designers' capabilities to solve

1 *European Commission, A New European Agenda for Culture* (Brussels: European Commission, 2018), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0267.

2 Notable attempts in this direction are being made in Western economies. One of the most recent examples is the New European Bauhaus (NEB), launched by the European Commission. NEB promotes an innovative and aesthetic approach to developing the Green and Digital transition toward which Europe is striving, with the direct involvement of people. Focusing on design, co-creation, inclusion, sustainability, and investments, the initiative also wants to prove the centrality of creativity and culture when confronted with the complexity of current socio-environmental challenges.

3 In the 1960s and 1970s, many notable thinkers saw the role of design potentially shifting in this direction. For example: Buckminster R. Fuller, *Utopia or Oblivion: The Prospects for Humanity* (Toronto, New York: Bantam Books, 1969); Tomas Maldonado, *La Speranza progettuale. Ambiente e società* [Design, Nature & Revolution. Towards a Critical Ecology] (Milano: Einaudi, 1970). More recently, human–computer interaction (HCI) and interaction design have built a discipline around translating technology for people; see for example: Graham Dove et al., "UX Design Innovation: Challenges for Working with Machine Learning as a Design Material," in *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (New York: ACM, 2017), 278–88.

4 Examples of new frameworks include: UNESCO, *Culture 2030 Indicators* (United Nations Educational, Scientific and Cultural Organization, 2019), https://unesdoc.unesco.org/ark:/48223/pf0000371562; John Siepel, et al.,

https://doi.org/10.1162/desi_a_00695

wicked or ill-defined issues[5]; nevertheless, recent discourse also has found designers to be somewhat unprepared for the future. Some attribute this shortcoming to design education.[6] Calling for a renovation of the principles and processes that drive design education, scholars argue that, although design problems have consistently changed in practice, design education has remained anchored in twentieth-century teaching and learning modalities and principles deriving from the First Industrial Revolution. For example, Michael Meyer and Don Norman describe four orders of challenges that have transformed methods, tools, and knowledge for design: performance challenges related to the know-how of designers; systemic challenges associated with the complexity of designed systems; contextual challenges related to the relationship with cultures, environments, and policies; and global challenges associated with the interconnection of systems.[7] These challenges require models of knowledge capable of going beyond established disciplines and toward a responsive reformulation of practice, where the boundaries of design are blurred and reconfigured according to needs.

From another angle, the ongoing debate often is characterized by concerns linked to new technologies and their effects both on design competencies and on the process of design innovation. Roberto Verganti, Marco Iansiti, and Luca Vendraminelli focus particularly on artificial intelligence (AI) to depict design in the innovation process of modern AI factories.[8] They claim that although AI still is used in limited ways, it is redefining the concerns of design. Algorithms are becoming the leading developers of highly personalized solutions (e.g., interfaces, selection/representation of content, and others), while designers shift their concerns to developing data feedback loops. These data feed the algorithm and support its learning cycle, while the non-human agent makes all the fine-grained design choices to tailor the product-service system to the final user.

Focusing on design approaches, Elisa Giaccardi and Johan Redström discuss the "more-than-human" as an evolution of human-centered design, in which objects (intelligent and data-fed) are no longer a passive result of problem-solving activities.[9] Instead, the direct participation of the output disrupts the traditional design process as algorithms become active agents whose interactions might modify values, methods, and responsibilities when designing. Giaccardi argues that this new role for artifacts incorporates three significant shifts: "(1) the *agential shift* toward the inclusion of things as partners in design, (2) the *temporal shift* toward always available opportunities for co-creation, and (3) the *infrastructural shift* toward unstable forms of value."[10] These shifts allow for different ways to generate and critique knowledge in design activities, and new meanings for the concepts of participation and

Creative Industries Radar. Mapping the UK's Creative Clusters and Microclusters (London: Nesta, 2020), https://www.pec.ac.uk/assets/publications/PEC-Creative-Radar-report-November-2020.pdf (accessed May 10, 2021).

5 Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4 (1973), 155–69; Peter G. Rowe, *Design Thinking* (Boston, MA: MIT Press, 1987); and Richard Buchanan, "Wicked Problems in Design Thinking," *Design Issues* 8, no. 2 (Spring 1992): 5–21.

6 Michael W. Meyer and Don Norman, "Changing Design Education for the 21st Century," *She Ji: The Journal of Design, Economics, and Innovation* 6, no. 1 (2020): 13–49; Sheila Pontis and Karel van der Waarde, "Looking for Alternatives: Challenging Assumptions in Design Education," *She Ji: The Journal of Design, Economics, and Innovation* 6, no. 2 (2020): 228–53; Patrick Whitney and André Nogueira, "Cutting Cubes Out of Fog: The Whole View of Design," *She Ji: The Journal of Design, Economics, and Innovation 6*, no. 2 (2020): 126–56; and Johan Redström, "Certain Uncertainties and the Design of Design Education," *She Ji: The Journal of Design, Economics, and Innovation* 6, no. 1 (2020): 83–100.

7 Meyer and Norman, "Changing Design Education for the 21st Century," 15–16.

8 Roberto Verganti et al., "Innovation and Design in the Age of Artificial Intelligence," J*ournal of Product Innovation Management* 37, no. 3 (2020): 212–22.

9 Elisa Giaccardi and Johan Redström, "Technology and More-Than-Human Design," *Design Issues* 36, no. 4 (Autumn 2020), 33–44.

10 Elisa Giaccardi, "Histories and Futures of Research Through Design: From Prototypes to Connected Things," *International Journal of Design* 13, no. 3 (2019): 139–55.

control in designing deserve further investigation. For instance, building on the agential shift, these new artifacts (or agents) need to be considered influential in the process of designing, holding power to make choices.

Other scholars also read the same transformation. For instance, Jodi Forlizzi argues for the need to supersede user-centered design and to move toward a notion of stakeholder-centered design. Forlizzi states that "we are no longer designing one thing for one person. Instead, we are doing stakeholder-centred design, which takes into account the notion of different entities interacting with and through products, services, and systems to achieve a desired outcome."[11] Forlizzi's argument is close to Giaccardi and Redström's idea of a "more-than-human" design. Here, designers need to accept that the outputs produced are no longer passive, near-perfect solutions. Instead, designers design systems (as the correlation between products, services, experiences, and more) that evolve and learn over time; they are dynamic and do not exit from the pencil of the creator as finished outputs. As the experience of designing moves toward devising these learning systems, designers need to examine the characteristics of their component agents more closely.

Strictly correlated with this shift is a discussion about the required knowledge necessary for designers to deal with these new horizons of the profession. In this article, I contribute to this debate by examining design knowledge and how an understanding of design knowledge could be updated. I do so by considering design knowledge as a collection of different cognitive processes aimed at developing artifacts for the human-made world, adopting Kolb's definition of learning as "the process whereby knowledge is created through the transformation of experience."[12] I discuss the change in design knowledge by examining how the characteristics of designed items have changed and by building on the theories of Neri Oxman and Richard Buchanan.[13] This approach allows for identifying the areas where creativity is breaking free from disciplinary silos to flow between physical, digital, metaphysical, and biological layers.

I propose in this article an updated map of the orders of design as a thinking tool and compass. With this proposal, my goal is to read the evolutions of design as it enters the Fifth Order of concerns, characterized by the centrality of mixed types of data both as input to and output from a design process. Today, design needs to dialogue equally with people and other "species" (machines and micro-organisms), all of which actively participate in reaching an objective. It also needs to find better ways to engage with ethical considerations linked to creating different types of experiences, breaking—where possible—the rules dictated by the business.[14]

11 Jodi Forlizzi, "Moving Beyond User-Centered Design," *Interactions* 25, no. 5 (2018): 22–23.

12 David A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development* (Englewood Cliffs, NJ: Prentice-Hall, 1984), 38.

13 Neri Oxman, "Age of Entanglement," *Journal of Design and Science*, https://doi.org/10.21428/7e0583ad; and Richard Buchanan, "Design Research and the New Learning," *Design Issues* 17, no. 4 (Autumn 2001): 3–23.

14 For example, design needs to incorporate ethical considerations better into digital experiences. Here, research is exploring what is considered addictive (e.g., David C. Evans, *Bottlenecks: Aligning UX Design with User Psychology* (California: Apress, 2017), the approaches and strategies that might lead to addiction, and how cultural and societal pressures can contribute to this phenomenon. In recent years, addictive technology has become central because it has determined the emergence of new (very profitable) business models based on commodifying behavioral data and capturing and retaining people's attention beyond what can be considered healthy. See, e.g., Thomas H. Davenport and John C. Beck, "The Attention Economy," *Ubiquity* (May 2001): 1-es; Shoshana Zuboff, *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power* (New York: Public Affairs, 2019); and Vikram Bhargava and Manuel Velasquez, "Ethics of the Attention Economy: The Problem of Social Media Addiction," *Business Ethics Quarterly* 31, no. 3 (2021): 321–59. Design plays a crucial role in crafting these experiences, as do algorithms that, learning from people's habits, can help generate addiction at both higher granularity and broader scale. See also Adam Alter, *Irresistible: The Rise of Addictive Technology and the Business of Keeping Us Hooked* (New York: Penguin Press, 2018); and Pierre Berthon et al., "Addictive De-vices: A Public Policy Analysis of Sources and Solutions to Digital Addiction," *Journal of Public Policy & Marketing* 38, no. 4 (2019): 451–68.

Finally, I propose a shift in the traditional principles of designing, away from the idea of reaching perfect solutions and toward learning systems that are good enough for now. In conducting this analysis, I provide grounding for further investigation by all researchers willing to inquire about the shifts into the "how" and the "why" of design, with a particular focus on design knowledge. In turn, updating the understanding of processes, capabilities, and avenues of applying design in contemporary society might be possible.

The New Meaning of "Artificial"

Studying the implications of the digital transformation on society, Alessandro Baricco argues that its advent has determined a revolution that he opposes to the sociological traits of the twentieth century.[15] He recognizes a few main characteristics of this revolution including the abolition of mediation (i.e., the role of the expert), the creation of a new digital layer for life beyond the physical one, the propensity toward the game as a preferred metaphor of life, and the choice of dynamism (i.e., multitasking) over stillness as an overarching value.

If we follow Baricco's analysis, these transformations massively influence design. All the digital world's objects, systems, and experiences acquire these same characteristics. Despite this influence, most designers remain anchored to models of industrial mass production and the development of solutions with long-life cycles. This mode of operation is driven by standardization, generalization, and economies of scale; the objective of design is to develop perfect, static, and long-lasting products. However, from the end of the 1990s onward, a new logic began to emerge; it was linked to the long tail of goods[16]: infinite choices, short life cycles, and tailored mass products. A product that contributed to launching this trend globally offers a suitable example: the first iPhone. When the first model was launched, Steve Jobs presented a revolution in the new notion of the smartphone. The first iPhone was no longer a functional object but an extension of the human: It could perform more than one specific function (i.e., take pictures, surf the internet) and connect people to their digital selves (i.e., emails and websites). The iPhone changed more than habits; it contributed to defining the relationship between people and their "digital prosthesis-machine,"[17] becoming one of the symbols of the dialogue between the physical and the digital. Objects belonging to this category have become enabling platforms for people, just as the iPhone-type smartphone became the first intelligent machine in their lives, succeeding where the personal computer had failed. At this temporal juncture, the over-

15 Alessandro Baricco, *The Game* (Milano: Einaudi, 2018).

16 Chris Anderson, *The Long Tail: Why the Future of Business is Selling Less of More* (USA: Hyperion, 2006).

17 Alessandro Baricco, *The Game* (Milano: Einaudi, 2018).

all ontology of physical objects began to shift toward learning bridges between worlds. With this bridge in place, services and entire experiences could dematerialize by moving into a digital layer (e.g., entertainment, music, and movies), thus sanctioning the entrance into what Baricco calls "The Game,"[18] or the new world dominated by the web and algorithms.

In light of this transformation, the founding logic of design—as a practice that devises these objects and experiences—needs updating. The changes not only involve novelties in the object of design—that is, the physical products and the elegant gestures connecting physical and digital—but also new issues of participation, power, and control. These issues intriguingly enter into the logic because different influential agents (i.e., data products) can now participate in the design process. Accordingly, the meaning of the word artificial in the title of Herbert Simon's book, *The Sciences of the Artificial*, also needs to be understood through new lenses.[19] Simon originally described design as creating sophisticated forms and concepts consistent with scientific and engineering principles. However, he never questioned the connection to the mass production logic of the First Industrial Revolution. Today, the meaning of the word *artificial* has broader connotations and goes beyond the indications needed to produce products industrially. *Artificial* now indicates learning agents interacting with people and the data that feed their learning process. This interaction at times results in dark patterns that lead to harmful digital experiences.[20] *Artificial* signals a necessity to model algorithms, and include other species, to make both of them centers of design innovation processes. All of these participants can become new centers for design innovation processes.

A notable example of this needed expansion is the work of Neri Oxman, head of the research group, Mediated Matter, at the Media Lab of the Massachusetts Institute of Technology (MIT) in Cambridge, MA. She works at the intersection between architecture and micro-organisms, using the tools made available by technological innovation to engineer nature. This work is done at the crossroads between science, biology, design, and art, adopting a trans-disciplinarity that makes her research a milestone for the design of the twenty-first century. In a 2016 article, she offered a different model to explain the entanglement between disciplines and the transformation of knowledge that occurs between them: the Krebbs Cycle of Creativity (KCC). The KCC is a map that describes the perpetuation of creative energy between the four modalities of human creativity: science, engineering, design, and art. She writes:

18 Baricco, The Game.

19 Herbert A. Simon, T*he Sciences of the Artificial* (Boston, MA: MIT Press, 1969).

20 Harry Brignull et al., "Dark Patterns—User Interfaces Designed to Trick People," https://www.deceptive.design/ (accessed May 10, 2021).

> Each of the modalities (or "compounds") produces "currency" by transforming into another: the role of science is to explain and predict the world around us; it "converts" information into knowledge. The role of Engineering is to apply scientific knowledge to the development of solutions for practical problems; it "converts" knowledge into utility. The role of design is to produce embodiments of solutions that maximize function and augment human experience; it "converts" utility into behavior. The role of art is to question human behavior and create awareness of the world around us; it "converts" behavior into new perceptions of information, representing the data that initiated the KCC in Science. At this "Cinderella moment"—when the hands of the KCC strike midnight—new perception inspires new scientific exploration.[21]

The cycle proposed by Oxman breaks design free from the limits of standard industrial production. It presents a new process through which creativity overcomes disciplinary silos by letting knowledge flow between physical, digital, metaphysical, and biological layers. This intuition is at the core of one of the most exciting fringes in design practice. In this metabolic view of creativity, design resides between the digital and the metaphysical worlds, dealing with perceptions and culture rather than with physical *materialities*.

An Updated Map of the Orders of Design

These reflections evolve further our understanding of the fields in which design operates. Scholars have already made significant contributions to articulating this evolution in connection to the expanding interests of the discipline. One of the most notable frameworks is Richard Buchanan's explanation of the four orders of design through which scholars synthesize the interests of the discipline.[22] Buchanan argues that design started—after the First Industrial Revolution—with a focus on communication, symbols, and images. It then evolved into artifacts, getting closer to engineering and architecture while adopting the principles of mass production. In the twentieth century, design moved toward devising more than physical outputs for industrial production; that is, it focused on results that were at the same time tangible and intangible, from processes to services and interfaces. This consolidated knowledge in design states that design works with interactions, mainly devising how people relate to other people. A further evolution for Buchanan is

21 Oxman, "Age of Entanglement," n.p.

22 Richard Buchanan, "Design Research and the New Learning," *Design Issues* 17, no. 4 (Autumn 2001): 3–23.

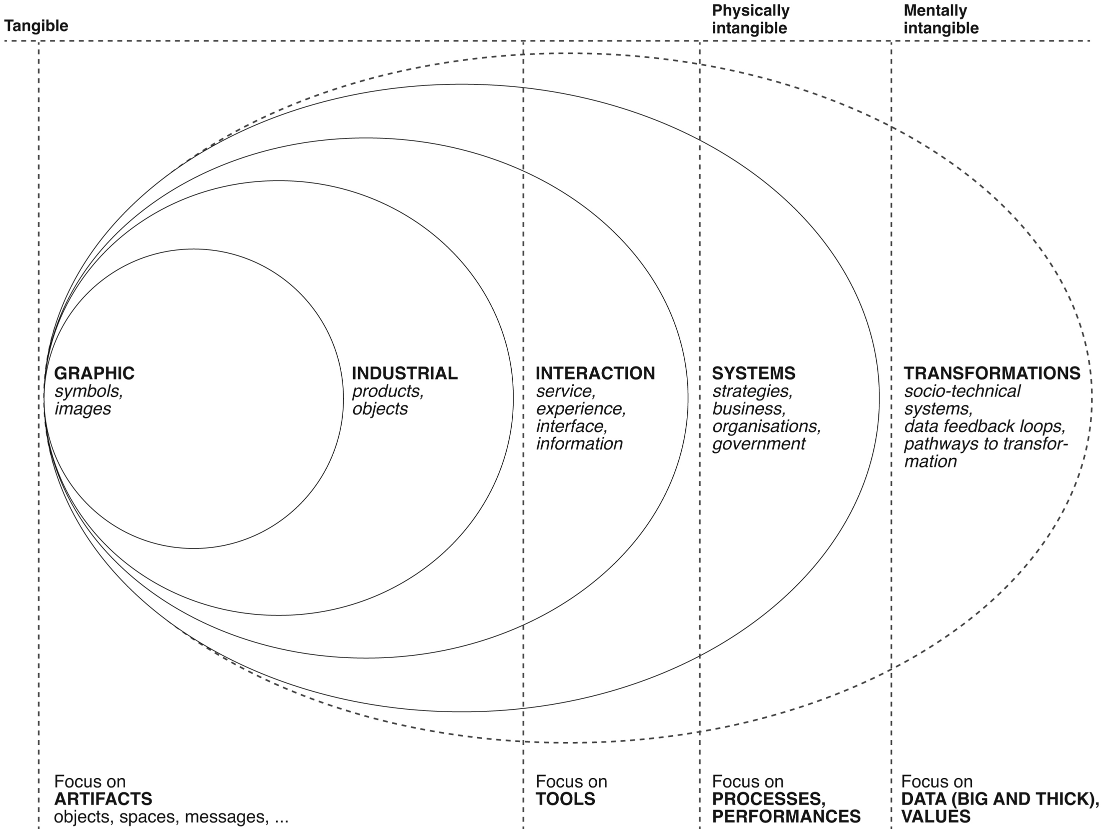

Figure 1
Five-Order Model of Design (Source: Developed by the author, drawing on Buchanan, 2001; Oxman, 2016; Giaccardi and Redström, 2020; and original work.)

This online image was revised from the original October 2022, in-print version to reflect a small but worthy adjustment to the final column as of January 2023.

designing the environments and systems within which all the previous objects and activities live: "Understanding how these systems work, what core ideas hold them together, what ideas and values—that is a fourth-order problem."[23]

Arguably, this fourth order has now expanded to a fifth order (see Figure 1). Intermingling Buchanan's ideas with the approach proposed by Oxman and contributions made by Giaccardi and Redström, we can state that design currently is moving beyond the development of systems and environments where people relate to each other. It is devising learning systems in which new and different types of *agents* act. These agents include mathematically engineered models that, once trained, do not always explain their problem-solving and decision-making processes; they are nature, micro-organisms, and other species that live and thrive outside of the control of humans. In this fifth-order problem, the relationships between humans lose centrality while bridges to interact with the other species participating in the creative endeavor become a focus. These species are simultaneously protagonists in the development of a solution and part of the solution itself; they

23 Ibid.

potentially open new complexities (linked to the dimensions of time, evolution, and learning involved) that the discipline has seldom encountered before. Here, design offers mainly the development of environments and infrastructures (i.e., digital platforms, data objects, and others) to achieve different goals, including engagement, decision making, and more.

Further, design uses different data types to read more than human needs (i.e., environmental, societal) because it is interested in supporting transitions and understanding their socio-political and cultural implications. However, this expansion does not imply the loss of interest in developing more typical outputs (e.g., objects, symbols, services, and interfaces). On the contrary, design often uses traditional skills to connect people to the new learning systems, experiencing tensions between what would be ethically desirable and economically viable. Many other disciplines also are exploring this tension both empirically and philosophically, linking to the broader discourse on the posthuman, where both advocates and critics can be found.[24] Design practice is weaker in this debate, both because it is hardly detachable from the business reality of companies and because more critical reflections are mainly theoretical and emergent, often remaining confined to the world of research and academic scholarship. Although the relevance of a discussion on the posthuman is already apparent in theory, a specific approach to value creation is still dominant in practice, leaving a gap when it comes to bridging considerations between these two worlds.

Fifth-Order Problems in Design

The map I propose in Figure 1 is a thinking tool and compass; it shows the evolution of design, moving beyond traditional industrial production models. Emerging practices can help exemplify how the fifth order of design is taking shape.

One element that is characterizing this debate is data. Discussions on data are one of the new arenas of ethical, cultural, and social debates; in modern society, in many ways, data is destiny and history, past and future at the same time. Data (and the machines that use them) are actively used in many digital environments increasingly to determine choices, influence people (e.g., the phenomenon of echo chambers), and predict their paths. Tech companies are increasingly steering innovation in this direction, thus pointing design toward mastering new competencies at the crossroads between stories and numbers. These new competencies are counterintuitive compared to how designers have traditionally emphasized user research and field observation: By empathizing and collecting qualitative data, the designer extracts insights, often

24 The posthuman concept—and related concepts, such as the non-human, the multispecies, the anthropocene, the more-than-human, the transhuman, and decentering of the human—resists binary categories and instead integrates the human and the non-human. It supports thinking about socio-technical systems as both socially constructed and society shaping. A wide range of social theories from diverse fields (e.g., science and technology studies, communications and media studies, and architecture, urban planning, and geography) adopt this philosophical approach to understand current complex societal problems while decentering humans. See, e.g., Laura Forlano, "Posthumanism and Design," *She Ji* 3, no. 1 (2017): 16–29; Silvia Lindtner et al.,"Reconstituting the Utopian Vision of Making: HCI After Technosolutionism," in *CHI '16–Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (New York: ACM, 2016), 1390–402, DOI: https://doi.org/10.1145/2858036.2858506; Danah Boyd and Kate Crawford, "Critical Questions for Big Data: Provocations for a Cultural, Technological, and Scholarly Phenomenon," *Information, Communication & Society* 15, no. 5 (2012): 662–79; Tarleton Gillespie, "The Politics of 'Platforms,'" *New Media & Society* 12, no. 3 (2010): 347–64; Natasha D. Schüll, "Data for Life: Wearable Technology and the Design of Self-Care," *BioSocieties* 11, no. 3 (2016): 317–33; Anna L. Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton: Princeton University Press, 2015); and Janine M. Benyus, *Biomimicry: Innovation Inspired by Nature* (New York: William Morrow, 1997).

characterized by their uniqueness, to guide innovation.[25] In ethnography, these types of data are also called thick data, or "precious data from humans that cannot be quantified."[26] They are enriched by understanding the deeper reasons behind behaviors and often are derived from tacit and unintentional actions. On the one hand, thick data have central significance for design; on the other hand, large amounts of data (i.e., big data) are the novelty for reading panoramic patterns of behaviors and for training algorithms. Thus, questions arise as to how these two types can be merged in design processes. Indeed, this merging is a crucial element in the fifth order of design, where the debate in the design research community involves at least two significant areas of reflection.

The first area is data conceptualization as a new modality to make sense of data beyond visualization. For instance, data physicalization (i.e., the practice of mapping data to physical forms) offers one means to break free from the "tyranny of the pixel" and experiment with different relationships between data and mind, as well as data and the world.[27] Dietmar Offenhuber offers a relevant overview of the evolution of this area of practice, stating that "data physicalization brings data from the unambiguous symbolic space into the real world, where data is a more complicated affair. As the physical manifestation of a data set becomes more elaborate and sensorily rich, data and display cannot be neatly separated."[28] This practice challenges the symbolic nature of data derived from the history of science. In physicalization, data assume a layered meaning to become matter that can be felt and manipulated, passed around, and weighted with a relevance strictly connected to the context in which the data are collected and displayed. Data physicalization artifacts become learning environments themselves and bridges for conversation between the source of the data, the observer, and the world. They are dynamic artifacts, subject to the evolution of time and the signs that time creates on any living matter; they are also data products fed by and based on specific data sets. Intriguingly though, these data sets do not follow the traditional conventions of data symbolisms but can be a conceptualization that feeds understanding on the complex issues that dominate contemporary society.

One of the examples Offenhuber uses exemplifies the argument: "Perpetual Plastic," by Liina Klauss, Skye Mor'et, and Moritz Stefaner, is an installation situated on a beach in Bali that arranges plastic debris collected directly from the beach in a Sankey diagram.[29] As Offenhuber describes it, the graph represents the fate of plastic waste, leading the observer to reflect on what and how much was discarded and on its unsettling actual lifespan beyond

25 Kees Dorst, "The Core of 'Design Thinking' and Its Application," *Design Studies* 32, no. 6 (2011): 521–32.

26 Clifford Geertz, *The Interpretations of Cultures* (New York: Basic Books, 1973); and Tricia Wang, "The Human Insights Missing from Big Data," TEDTalk, https://www.youtube.com/watch?v=pk35J2u8KqY (accessed September 20, 2020).

27 Andrew Vande Moere, "Beyond the Tyranny of the Pixel: Exploring the Physicality of Information Visualization," in *Proceedings of IEEE International Conference on Information Visualisation* (New York: ACM, 2008), 469–74.

28 Dietmar Offenhuber, "What We Talk About When We Talk About Data Physicality," in *Proceedings of IEEE International Conference on Computer* Graphics and Applications 40, no. 6 (November-December 2020): 4.

29 The project, Perpetual Plastic, is available at http://perpetual-plastic.net (accessed September 22, 2020).

human use. As an installation, it not only establishes meaningful relationships with its surroundings but also creates conversations with them, whether among the people who observe it or the wind and water that modify its look by progressively destroying it. Through these conversations, the installation creates a rich learning environment, where data participate in developing the solution and are the solution, simultaneously. It exemplifies a metabolic cycle of creation and destruction; it looks beyond the relationship between humans and their needs, instead centering on the environment's needs and providing a platform for conversation.

A second area is data exploitation and (ab)use as a new way to study behaviors and propose new user experiences. For instance, this happens in the development of AI-based systems. However, research is finding that designers are somewhat unprepared to envision and prototype AI systems.[30] Here, one challenge seems to be the dynamic nature of these systems. Designers seem ill-prepared to sketch how an AI-based system can adapt to different users and contexts or prototype the inference errors that a not-yet-developed system might make. AI's technical complexity, demand for data, and unpredictable interactions seem to be elements that designers have not yet understood how to master. Qian Yang and colleagues identify two attributes of AI that are central to the competence deficiencies of designers: capability uncertainty, described as uncertainties surrounding what the system can do and how well it performs; and output complexity, or the complexity of the outputs that the system might generate.[31]

The body of knowledge that tries to understand how designers might improve their preparedness in dealing with AI-based systems is controversial. It conveys the necessity to develop solutions that adopt a user-centered perspective but fails to consider the system's participation in designing. In these cases, the learning agent contributes to the development of the solution and is the solution simultaneously, thus increasing the complexity of designing. Fabien Girardin and Neal Lathia propose a different approach.[32] They focus on the feedback loop by which data are fed into a learning system, claiming that this input is central to designing digital services that evolve and adapt by learning from their users and the context in which they operate. Rather than attributing shortcomings to designers, the authors argue that the design of digital services underpinned by a feedback loop should bring together various disciplines. At the core of the solution is a tight partnership between designers and data scientists because "systems with feedback loops can only be imagined, built, and improved with a holistic view of how users' experiences are affected by interactions between data, algorithms, and interfaces."[33]

30 Marco Gillies et al., "Human-Centred Machine Learning," in *CHI EA '16–Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (New York: ACM, 2016), 3558–65; P. Hebron, "Machine Learning for Designers," O'Reilly Media (2016); and Philip van Allen, "Prototyping Ways of Prototyping AI," *Interactions* 25, no. 6 (October 2018): 46–51.

31 Qian Yang et al., "Re-examining Whether, Why, and How Human–AI Interaction Is Uniquely Difficult to Design," in *CHI Conference on Human Factors in Computing Systems* (New York: ACM, 2020), 1–13, https://doi.org/10.1145/3313831.3376301.

32 Fabien Girardin and Neal Lathia, "When User Experience Designers Partner with Data Scientists," in *The AAAI Spring Symposium Series Technical Report: Designing the User Experience of Machine Learning Systems*, Mike Kuniavsky, Elizabeth Churchill, Molly Wright Steenson, eds. (Palo Alto, CA: The AAAI Press, 2017).

33 Ibid., 1.

As a result of this collaboration, each product or service is a "living, breathing thing" that leads to a different kind of design altogether. To illustrate, Amazon Echo is an object whose hardware has the mere function of helping people relate to its software. Its core is the learning algorithm that continually evolves during use by adding new functionalities. These types of products are the new machine-prosthesis after the iPhone—the learning systems that drive the emergence of new kinds of human-machine relationships as opposed to interactions.[34]

Girardin and Lathia describe a set of different experiences that can be mediated by machine learning and identify several upcoming themes for design. They include design for discovery, referring to recommender systems; design for decision making, referring to information services; design for uncertainty, which has designers using the uncertainty of machine predictions to inform users differently; and design for engagement, referring to systems that fight for human attention.

Fifth-order learning systems are solutions that simultaneously act on a technical layer—where technology transforms an activity, a task, or a performance—and on a social layer—involving the development of new competencies, values, and practices in a specific community, group, or organization. Aligning this socio-technical approach to design practice is not new; scholars have long underlined the importance of situated projects and the necessity to align the technical performance with contextual needs.[35] Nevertheless, the challenges of learning systems demand the renovation of the role of designers complementing a technical endeavor—the more traditional one linked to designing shape and function—with a sociological role, where a project starts from problem setting (or the understanding of the most pressing challenges) to provide hands-on support for transformation to communities and organizations. A data-informed approach should also be added whereby stories commingle with numbers and human values dialogue with mathematical models. The resulting objects of this fifth-order design are socio-technical systems materialized through data feedback loops, data conceptualizations, and wider pathways to transformation. These outputs emerge from a shared development among designers, humans, and other participating agents engaged in meeting social, cultural, and technical challenges.

Design Knowledge in the Fifth Order of Design

This fifth order of design offers new perspectives on design knowledge. In it, reflecting on the knowledge required by designers to deal with the new horizons of the discipline is crucial. The Merriam-Webster dictionary defines knowledge in several ways:

34 Genevieve Bell, "The Next Wave of AI is Rooted in Human Culture and History," interview by Mona Lalwani, Engadget (website), August 16, 2016, https://www.engadget.com/2016-08-16-the-next-wave-of-ai-is-rooted-in-human-culture-and-history.html (accessed May 10, 2021).

35 Victor Papanek, *Design for the Real World* (London: Thames and Hudson, 1972); and Victor Margolin, ed., *Design Discourse: History, Theory, Criticism* (Chicago: University of Chicago Press, 1989).

1 a (1): the fact or condition of knowing something with familiarity gained through experience or association; (2): acquaintance with or understanding of a science, art, or technique

b (1): the fact or condition of being aware of something (2): the range of one's information or understanding // answered to the best of my *knowledge*

c : the circumstance or condition of apprehending truth or fact through reasoning: COGNITION

d : the fact or condition of having information or being learned // a person of unusual *knowledge*…

2 a : the sum of what is known: the body of truth, information, and principles acquired by humankind

b archaic: a branch of learning. …[36]

Building on this definition, Ken Friedman distinguishes between information and knowledge, arguing that "knowledge embodies agency and purpose. In this, it differs from information. Information may be stored in information systems. Knowledge is embodied in human beings. Knowledge creation is an intensely human act."[37] In performing this human act, designers—like any other professional—create their knowledge through the interaction of many different learning activities, thus blending thinking, experience, and action.

On the one hand, design knowledge can be described in terms of its form. In this sense, it is not different from the knowledge of other disciplines, creating explicit, discussable, transferable, and accumulable learning. On the other hand, to articulate design knowledge, one could refer to thinking and learning processes and to the collection of cognitive artifacts that designers typically use to embody their activities. These processes and artifacts might include visions, scenarios, utopias, and dystopias[38]; technical representations of specific objects, interactions, or experiences; and sense-making artifacts to engage people and organizations in collective reflection. Central to this way of understanding design knowledge is a notion of representation and visual intelligence that Walter Gropius first introduced.[39] Later, several other scholars supported this view, including Horst Rittel, Donald Schön, Nigel Cross, Bryan Lawson, and Kees Dorst.[40] For example, Rittel argued that the privileged place of action for design is the world of the imagination, where ideas are born and manipulated and where using concepts rather than real things is possible. This possibility makes creating models—as a means of manipulating reality—all the more attainable. Among the means helpful in producing such models, Rittel lists sketches, perspective and three-dimensional drawings, diagrams,

36 *Merriam-Webster's Collegiate Dictionary* (Tenth edition) (Springfield, MA: Merriam-Webster, Inc., 1993), 647.

37 Ken Friedman, "Creating Design Knowledge: From Research into Practice," IDATER 2000: International Conference on Design and Technology Educational Research and Development (Loughborough, UK: Department of Design and Technology, Loughborough University, 2000).

38 Gilberto Corretti, "Archizoom e futurismo," [Archizoom and futurism] *Archizoom e futurismo* [Archizoom and futurism] (2012): 173–84; and Marie T. Stauffer, "Utopian Reflections, Reflected Utopias: Urban Designs by Archizoom and Superstudio," AA Files 47 (2002): 23–36.

39 Walter Gropius, "Is There a Science of Design?" *Magazine of Art* 40 (December 1947), reprinted in Walter Gropius, *Scope of Total Architecture* (1956; New York: Collier Books, 1962), 30–43.

40 Horst Rittel, *The Reasoning of Designers*, Proceedings of the International Congress on Planning and Design Theory (Boston, MA, August, 1987); Donald Schön, *The Reflective Practitioner: How Professionals Think in Action* (New York: Basic Books, 1983); Nigel Cross, "Designerly Ways of Knowing: Design Discipline Versus Design Science," *Design Issues* 17, no. 3 (Winter 2001): 49–55; and Brian Lawson and Kees Dorst, *Design Expertise* (Oxford: Architectural Press, 2009).

and models; each of these means represents a method to visualize and translate ideas to communicate, discuss, and realize them. Nigel Cross also gives a privileged role to the ability to use imagination and drawing in design as a means of problem-solving.[41] Bryan Lawson argues that the knowledge accumulated or developed by the designer is expressed through visual representation because, again, this allows manipulation of ideas and reality.[42] Finally, Christofer Jones argues that visualization and representation techniques are essential because they provide designers with a greater perceptual span and understanding of issues.[43] Accordingly, visual intelligence can be considered a privileged means to learning in design; the resulting representations (e.g., scenarios, prototypes, utopias, dystopias, and others) are the cognitive artifacts through which designers embody and share their knowledge.

In dealing with fifth-order problems, these cognitive artifacts take on new instances. In particular, designers increasingly deal with problem-setting rather than only problem-solving. The example of AI factories provided by Verganti and colleagues explains this distinction clearly: Algorithms increasingly will become more efficient than humans at implementing and tailoring solutions; thus, humans will deal with the earlier phases of the creative process.[44] In this context, visual thinking needs to become a knowledge creation strategy to understand complex problem areas. Consequently, the purpose of representation must be expanded toward embodying abstract concepts and aiding understanding of systemic complexities. Here, the practice of *visual problem seeking* could be an example of using non-linear representations of ideas to adopt a *designerly* method of reasoning for knowledge generation.

Visual intelligence is only one example of how design knowledge might be rediscussed. Deciding what design knowledge is appropriate for the twenty-first century is a very complex task, further challenged by the tendency of designers to often work trans-disciplinarily. Thus, the knowledge they need can vary highly in the movement from one project to the next. However, thinking methods and cognitive artifacts can differentiate designers from other professionals, offering different approaches to complexity.

Shifting Principles of Design

A further critical discussion relates to updating a few fundamental principles that are direct descendants of the twentieth-century avant-garde; that reflect the artistic, social, and cultural beliefs of the time; and that still are being applied in many contexts and practices. In the First Industrial Revolution perspective, these principles set precise characteristics for being a designer—namely, the principle of iteration between form, function, and process to achieve

41 Cross, "Designerly Ways of Knowing."

42 Brian Lawson, *How Designers Think: The Design Process Demystified* (Oxford: Architectural Press, 2007).

43 Christopher Jones, Design Methods: Seeds of Human Futures (1970; rpt New York: John Wiley & Sons, 1981).

44 Roberto Verganti et al., "Innovation and Design in the Age of Artificial Intelligence," *Journal of Product Innovation Management* 37, no. 3 (2020): 212–22.

a complete, near-perfect result and the notion that design is primarily a problem-solving activity. The Digital Revolution questions these principles. For instance, following the characteristics of learning systems, the near-perfection attribute of artifacts no longer is a relevant value. Instead, the digital world pushes toward the notion of the *good enough, for now*, coming to terms with the fact that millions of alternative versions can be proposed in a short time (often developed by algorithms rather than humans). Accordingly, problem-solving no longer is the most relevant activity for design. In an uncertain world, establishing what problems are worth exploring is a priority interest: Half of these—the so-called global problems or sustainable development goals—are too large to be addressed by a single professional or company. In contrast, the other half is related to behaviors that are very specific and local.

In the future, design should no longer only be about delivering outputs for these local situations. Instead, problem seeking or visual problem seeking could become one of the new knowledge areas to be cultivated, needing new design methods and practices. Further, despite claiming to be more attentive to users' needs and lived experiences, design is still developing products, services, and systems that only reductively integrate race, class, gender, sexuality, and ability. This lack of integration probably results from the ways the market (i.e., relationships between funders, clients, start-ups, designers, retailers, and users) fails to account for the needs of specific individuals by favoring others, as well as the high level of dependence of design on the market itself. To develop more inclusively, design knowledge increasingly needs to integrate methods and tools that are suitable for considering new categories of needs and new learning *agents* as equal stakeholders in the process. The entire design community needs to actively steer toward these developments.

In the same way, as design addresses the challenges of new technologies, the societal, environmental, and ethical challenges need to be framed to keep developing relevant solutions for people and the planet. These developments face significant obstacles, mainly linked to the economic models that drive design in the commercial sphere. Acknowledging and thinking critically about them is crucial to allowing design(ers) to participate in steering development and innovation in sustainable directions. As we continue to extend the human via digital technologies and grapple with the effects of climate change, these reflections need to become more frequent to determine the impact that design might want to have on the world.